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THE INSTITUTE OF PETROLEUM

AN Ordinary General Meeting of the Institute of Petroleum was held at Manson House, 26 Portland Place, London, W.1, on Wednesday, September 13, 1950, the President, Mr C. A. P. Southwell, M.C., in the chair.

The Minutes of the preceding meeting were read, confirmed, and signed.

THE GENERAL SECRETARY (D. A. Hough) read the list of members elected since the last general meeting, and other announcements.

THE PRESIDENT: I am sure you would all wish me to say how pleased we are to welcome here Mr Cabot, Mr Edminster, and Mr Stokes. These gentlemen are joint authors of the paper which is to be presented to-night by Mr Cabot; and his colleagues Mr Edminster and Mr Stokes will illustrate it by slides and a film.

Mr Cabot is managing director of Cabot Carbon Ltd. He is a member of the Society of Chemical Industry, and his name is well known to us in the petroleum industry. He is a Harvard man; and I was very interested to hear that not only is he a Harvard technical graduate, but a postgraduate of the Harvard business administration course.

Without further delay I will call on Mr Cabot.

(Mr Cabot presented the following paper, and his colleagues illustrated by slides and a cinematograph film, in technicolor, the process of manufacture of furnace carbon black, the transport of the finished product, and its many uses.)

THE MANUFACTURE OF FURNACE CARBON BLACK FROM LIQUID HYDROCARBONS AT ELLESMERE PORT

By LOUIS W. CABOT,* J. W. EDMINSTER,† and C. A. STOKES‡

SUMMARY

The production of carbon black in Great Britain technically and economically became possible only after the development of a new process using liquid hydrocarbons rather than natural gas as a raw material. The process gives a carbon black of higher quality in several respects.

Carbon black is an extremely fine black pigment used primarily for reinforcing rubber.

The new plant just completed at Ellesmere Port is a modification of the furnace process, with the addition of smoke scrubbing and tail gas recovery equipment. Only certain raw materials can be used, which are at present available only in America. But British raw materials can doubtless be used in the future.

* Managing director, Cabot Carbon Ltd.
† Technical superintendent, Cabot Carbon Ltd.
‡ Director of research and development, Godfrey L. Cabot Inc.

Introduction

Economic Feasibility

Perhaps the first question of interest concerning the manufacture of furnace carbon black at Ellesmere Port is the question of why this becomes economically feasible at this time. Carbon blacks have been used in the U.K. for many years, and it might be thought that carbon blacks would have been manufactured in the U.K. long before this. As long as natural gas was the raw material this was impossible. The chief factor that now makes it possible is the development in the U.S. of high-yield hydrocarbons. These liquids are available anywhere because they can easily be transported, whereas natural gas is only available at reasonable cost where it is produced, and then only in remote sections away from other markets. Coincidental with this development in the U.S. has been the rapid increase in the price of natural gas. This has made the channel-black process, which can use only natural gas, less and less desirable from an economic standpoint compared to the newer oil-black process.

Understandably, the desire to cut down imports into the U.K. is also a factor influencing the beginning of a carbon-black industry in Britain. But this is not a controlling factor, since manufactured rubber articles are an important export from the U.K. The value of these manufactured rubber exports greatly exceeds the value of the imported carbon black, so that there would be no question about continuing to import carbon black if it were not possible to produce it in the U.K. As a matter of interest the statistics on imports of American carbon black to the U.K. and the British Commonwealth are shown in Table I.

Table I

Imports of Carbon Black from the U.S. to the U.K. and British Commonwealth

		Channel black	Furnace black	Total
		Millions of pounds.		
U.K.	1947	54	26	80
	1948	69	25	94
	1949 (est'd)	44	27 *	71
Total Commonwealth excluding the U.K.	1947	28	6	34
	1948	30	8	38
	1949 (est'd)	27	6 †	33

* Including 8,000,000 lb of furnace oil black.
† Including 400,000 lb of furnace oil black.

Quality Advantages

Not only has the process for making furnace blacks from oil changed the economic situation, but it has also given the rubber compounder a considerable bonus of quality of carbon black. The carbon blacks made from oils are characterized by a high degree of " structure " and surface activity which seem to give these blacks unique dispersing and wearing qualities in rubber. Some adjustment of factory processing techniques has been

necessary in order to permit the most advantageous use of these new blacks. Incidentally, the new blacks, while they are particularly suitable for the G.R.S. and low-temperature-type synthetic rubbers, are also very satisfactory for use in natural rubber. This is demonstrated by the figures in Table I, showing considerable imports of high-abrasion furnace black made from oil. The advantageous quality characteristic of oil furnace blacks is also demonstrated by the statistics on U.S. carbon-black production shown in Fig. 1.

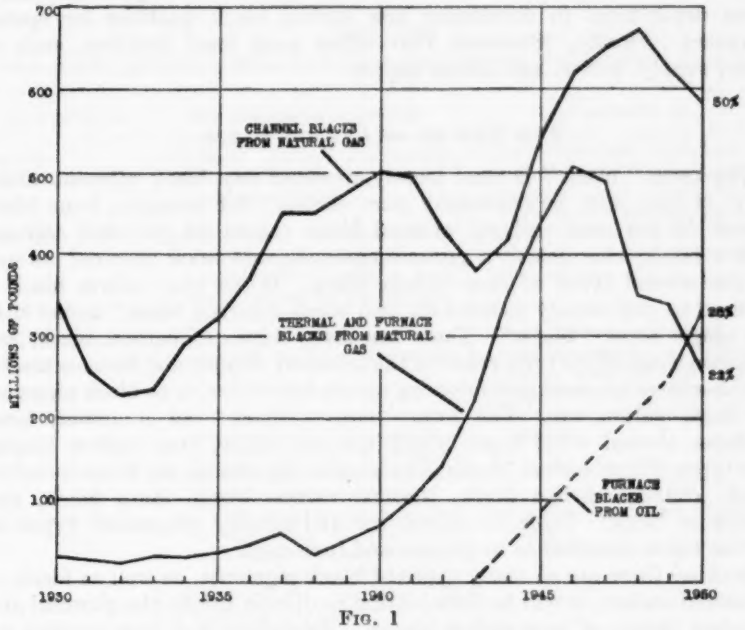

FIG. 1

CARBON BLACK PRODUCTION IN THE U.S.A.

In this graph it is seen that since about 1944 there has been a rapid increase in the production of furnace blacks from oil. This increase has been largely at the expense of the production of furnace blacks from natural gas and somewhat at the expense of the production of channel black from natural gas. The estimated production rates for 1950 indicate that 28 per cent of all U.S. carbon black will be produced from oil by the furnace process, 22 per cent from gas by the furnace process, making a total of 50 per cent blacks, leaving 50 per cent to be produced by the older channel process using natural gas as fuel. It is anticipated that in as little as five years fully half of the total U.S. carbon black production will be the newer oil furnace blacks.

Location of Plant

Ellesmere Port was selected as a carbon-black plant site for various reasons which may be of some interest. In the first place, Ellesmere Port

can be reached by ocean-going tankers. This is a very important consideration to a carbon black producer, since his fuel is a very important item of cost, and freight cost is necessarily important. In the U.S. the trend is to locate furnace black plants either adjacent to a very large refinery or on tide water. Ellesmere Port is a refinery centre and is close to other large refining centres such as Manchester. An important advantage of Ellesmere Port which is not often found in the U.S. is the close proximity to large rubber goods factories; this makes it possible to give good service to the rubber compounder and to work closely with his technical development department in developing new carbon black qualities for special purposes. Finally, Ellesmere Port offers good local facilities, such as water supply, power, and labour supply.

The Nature of Carbon Black

The term "black" is used loosely to cover any black pigment which may, or may not, be essentially pure carbon; for example, bone black (about 15 per cent carbon), mineral black (about 40 per cent carbon), willow black, vine black, or ground-pigment-grade wood charcoal, as well as the several types of true carbon black. When true carbon black is referred to, one usually includes the two words "carbon black" rather than the single term "black." There are many types of carbon black, but common usage of the term refers to the so-called channel and furnace blacks, whether these are used as reinforcing agents for rubber, or as black pigments for inks, paints, etc. The term "carbon black" as commonly used excludes several other types which are, in reality, true carbon blacks. The types of true carbon blacks of industrial importance are furnace carbon black, channel carbon black, thermal carbon black, lamp black, and acetylene black. Table II shows the industrially important types of carbon black classified as to process and fuels used.

Because there are so many types of black pigments, as well as forms of industrial carbon, it will be illuminating to discuss briefly the physical and chemical nature of true carbon blacks. Excluding that form typified by diamond, there are three general types of carbon among the various industrial carbons. These are the amorphous variety, the turbostratic variety, and the graphitic variety. The amorphous variety is best illustrated by ordinary wood charcoal, in which the only apparent ordering of the carbon black atoms is what remains from the original cellulosic structure. The graphitic variety is a true crystalline form of carbon with the well-known three-dimensional symmetry of graphite. On the other hand, turbostratic carbon, which is illustrated by carbon black, has symmetry in two dimensions so to speak. That is, it consists of carbon atoms in hexagonal planar spacing, but the planes are not arranged with respect to each other in perfect symmetry as in graphite. This arrangement is brought out by the analogy to a pack of playing cards. When the perfectly arranged pack is taken from the box it is like graphite. If the cards are skewed slightly by twisting them back and forth through the pack from top to bottom, it is like the carbon black structure. If a great number of skewed packs were loosely clustered together in the form of a spherical snowball-like aggregate, it would be like the aggregate of turbostratic carbon

"crystalites" making up the individual carbon black particles. It is this individual carbon black particle that is seen by the electron microscope.

Industrial carbon blacks have mean particle diameters ranging from 10 to 500 milli-microns. All true carbon blacks, that is furnace, channel, thermal, lamp, and acetylene have this same structure, but these carbon blacks vary in the degree of disorder in the crystalites, the size of the crystalites, the size of the primary particles, the degree and type of agglomeration of the primary particles, and the physical and chemical nature of the primary particle surface.

TABLE II

Carbon Blacks Classified by Major Features of Manufacturing Process and by Fuels Used

Type of black	Major features of process	Raw material fuels
Furnace . .	Confined partial combustion under controlled high-turbulence conditions.	Liquid coal-tar distillate or petroleum hydrocarbons; natural gas; liquid hydrocarbons and natural gas.
Channel . .	Impingement or unconfined partial combustion flame on cooled metal surface with access of air to oxidize surface of black.	Liquid coal-tar distillate hydrocarbons and town's gas; natural gas.
Thermal . .	Regenerative cracking on refractory surfaces in absence of air.	Direct process natural gas; by-product process natural gas; liquid coal-tar distillate or petroleum hydrocarbons.
Lamp black .	Confined partial combustion under relatively uncontrolled low-turbulence conditions followed by admission of air to oxidize surface of black.	Liquid coal-tar distillate hydrocarbons.
Acetylene black .	Confined exothermic cracking of acetylene at extremely high temperatures; confined endothermic extremely high-temperature cracking of hydrocarbon gases.	Acetylene; paraffinic or olefinic gases.

The remarks on the physical and chemical nature of carbon black are important largely to emphasize the extreme degree of manufacturing control necessary to get qualities suitable for reinforcing rubber or for pigment uses. Carbon black is the most finely divided pigment made in large tonnage quantities, and the control of this extremely fine particle size within narrow limits produces many grades for different uses and necessitates careful selection of the raw materials and the process equipment. Carbon black can be easily made by setting fire to an open pool of oil, as often happens when lightning destroys and fires an oil-storage tank, but unfortunately, neither a satisfactory yield nor quality results, and, furthermore, the carbon black must be collected, which is one of the most difficult problems of the industry. When it is realized that carbon black is produced in the form of an aerosol of suspended agglomerates having an agglomerate diameter range from about 10 to 500 mμ, it can be seen that collection of this carbon is not an easy problem. While carbon black smoke is absolutely innocuous as an industrial waste, it is by far the most easily

visible of all industrial waste. Since the carbon black producer is deliberately producing soot in large quantities he is expected to collect all of it out of his exhaust, even though his neighbour a half a mile away can sometimes produce soot accidentally in conjunction with a boiler furnace with much less complaint from the surrounding populace. Carbon black as collected often has a bulk density as low as 3 lb/cu. ft. A powder of this sort presents most exasperating problems of conveying and handling, and it is nearly impossible to conceive of a process so clean that the workmen who package the product will not become almost completely blackened in a few hours. Except for the packaging end, however, a modern furnace black plant can be made comparatively clean.

Process and Equipment for Carbon Black Manufacture

Carbon Black Furnaces, Collection, and Processing

The overall process of preparing carbon black for the consumer involves three major stages: (i) the actual formation of the black, (ii) its collection in a fluffy or powdery stage, and (iii) modification of the powdery black to denser, more conveniently handled pellets. A schematic diagram of such a plant (at Ellesmere Port) is shown in Fig. 2.

The first stage or actual formation of the carbon black from an oil is the result of partial combustion accompanied by thermal decomposition and the building up of fully dehydrogenated fragments into carbon particles. What comprises a suitable liquid hydrocarbon for black manufacturing will be dealt with more fully later in this paper. The heat necessary for cracking the hydrocarbon to black is supplied by combustion of a fraction of each gallon of the hydrocarbon entering the carbon black furnace. This heat released decomposes the remaining fraction of each gallon of the hydrocarbon into its major components, carbon (as carbon black) and hydrogen. Obviously, to obtain a high yield of carbon black from a gallon of oil the fraction of the gallon which is burnt must be kept to a minimum.

In a commercial carbon black production unit there is a battery of furnaces, the black and flue gases from each furnace discharging into a common manifold in which primary cooling is accomplished by water injection. The carbon black furnace itself is a refractory-lined cylindrical steel shell. The cooling manifold is made of unlined steel. As the combustion gases leaving the refractory lined furnace are over 2500° F, the temperature is lowered to about 1000° F to protect the cooling manifold.

To maintain the uniform quality of black demanded by the rubber compounder, it is highly important continually to measure and control the flow of carbon black raw materials: that is, the liquid hydrocarbon and air. Automatic flow-control instruments are used with the combined result of keeping operating manpower to a minimum and keeping quality more uniform than would be obtained if manual operation were used.

Thus far the first stage is completed—the actual formation of the carbon black.

At this point the second stage begins, that of separating the black from the flue gases in which the black is carried along as an aerosol. Since the particles of carbon black are so small, the usual methods of separating dust from a gas are not readily adaptable. It is, therefore, necessary in the

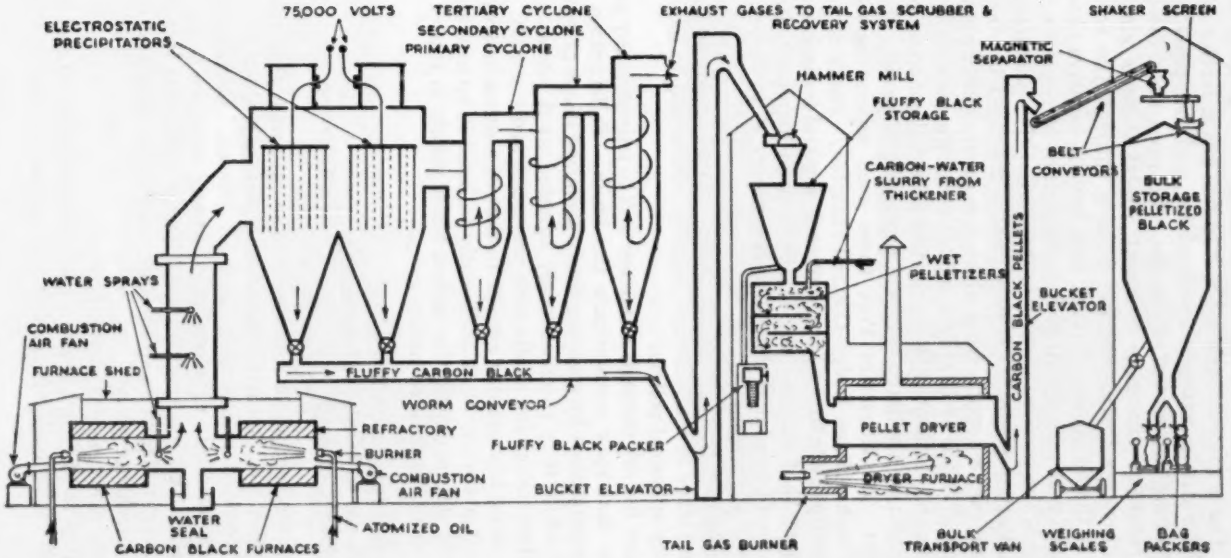

FIG. 2

CARBON BLACK FURNACES, COLLECTION, AND PROCESSING

carbon black industry to use the Lodge–Cottrell process of electrical precipitation. The aerosol of carbon black in flue gas is further cooled to 450° to 500° F by water injection in a vertical flue, and then passed through a chamber containing two sets of electrodes. Between these electrodes a unidirectional potential difference of about 70,000 volts is maintained. The electrical discharge ionizes the gas passing through the field. The ultimate result is that particles of black that have a negative charge and those that acquire a negative charge by attachment of negative gas ions are drawn towards the positive collecting electrode. The accumulation of black on the collecting electrodes is periodically dislodged by mechanical rapping and drops into a hopper, from which it is continuously removed by a screw conveyor. This is ordinarily a small part of the production. The increase diameter and density of these clusters allows them to be removed from the gas stream by the more common procedure of passing through a cyclone separator. At Ellesmere Port three such separators follow in series after the high-voltage Lodge–Cottrell chamber. Black removed in these three separators falls to the hopper of each one and is discharged into the same conveyor that empties the Lodge–Cottrell hoppers. The combined action of the Cottrell and the cyclones removes 90 to 95 per cent of the black from the gas stream.

The black, in the dry, fluffy, low-bulk-density state is ready to pass into the third and last stage of manufacture, namely, conversion to moderately hard, high-density spherical pellets.

The black is now fed dry through a hammer mill to pulverize any particles of coke or scale that may contaminate the black. Pelletization of the fluffy black is accomplished by spraying finely atomized drops of water into the fluffy black while it is simultaneously agitated as it passes through horizontal cylinders containing shafts with projecting arms or rods. These move the black along in a manner similar to that of a screw conveyor and at the same time agitate the black sufficiently to build it up into spherical pellets. The final step is drying the carbon black pellets in rotary driers. Desirable qualities of the finished pellets are :—

(1). High density (22–28 lb/cu. ft).
(2) Resistance to breakdown in transit.
(3) A minimum of dust.

Before the pellets are bagged for shipment to the customer, they pass over a magnetic separator and through a vibrating screen to remove first tramp iron and then oversized pellets that may be present. Carbon black is formed into pellets primarily to reduce the dust and nuisance to the customer. Pelleted black also incorporates much faster on mixing into rubber. In addition, pelletized blacks mean cheaper packaging costs and reduced requirements of warehouse space.

Fig. 3 shows the arrangement of the furnaces.

Fig. 4 shows from right to left the furnace sheds, the Cottrell and cyclone collectors, the pelletizing buildings, and the storage and warehouse facilities.

Tail-gas Scrubber and Recovery System

It was mentioned earlier that the combined action of the Lodge–Cottrell precipitator and the cyclone separators removes 90 to 95 per cent of the

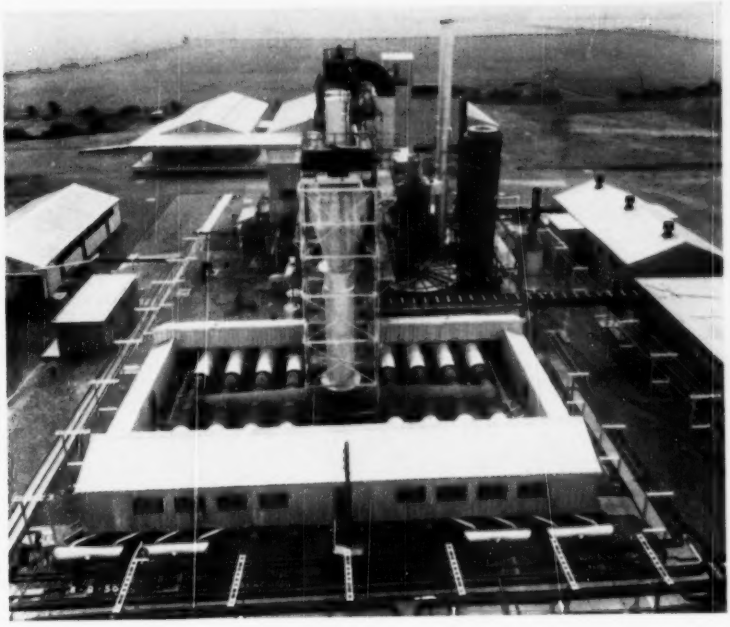

FIG. 3

THE FURNACES

FIG. 4

A GENERAL VIEW SHOWING (*right to left*) FURNACE SHEDS, COTTRELL AND CYCLONE COLLECTORS, PELLETIZING BUILDINGS, AND STORAGE AND WAREHOUSE FACILITIES

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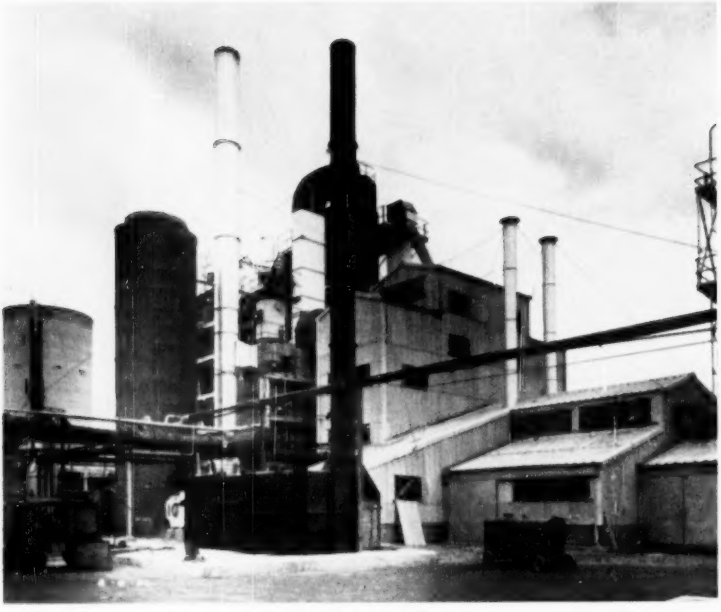

FIG. 6

(Right to left) PELLETIZING BUILDING, WET SCRUBBER AND WET PRECIPITATOR, AND DIRECT-CONTACT GAS-COOLING TOWER

black from the gas stream. If the remaining 5 to 10 per cent of black is discharged into the atmosphere through a stack, a smoke nuisance may be created in the community and much valuable product is lost. Therefore a final cleaning action is taken (Fig. 5).

The gas (and remaining black) is subject to a water-spray scrubbing action, which removes about 75 per cent of the remaining black. The water scrubbing also removes from the gas sulphur dioxide and sulphur trioxide formed from the sulphur present in the oil. Because of the corrosive nature of this acid-scrubbing water, it is clear that a liquid hydrocarbon low in sulphur is a desired raw material.

Final cleaning of the gas is accomplished by passing the gas through a "wet" Lodge–Cottrell precipitator chamber. A "wet" precipitator operates similarly to the so-called "dry" precipitator previously mentioned, except that the black and gas are at a lower temperature and higher humidity. The black depositing on the collecting electrodes is removed by washing with water sprays, rather than by mechanical rapping. Overall efficiency of the total carbon black collection system is better than 99·5 per cent.

The clean gas leaving the wet precipitator contains enough hydrogen and carbon monoxide so that after dehumidification it has a fuel value similar to the waste gases from a blast furnace. The low-calorific-value fuel can be used to fire boilers, heaters, driers, etc. Part of the flue gas is dehumidified by direct contact with water in a spray tower, the water being cooled in turn in a natural draft cooling tower.

The black-water slurry formed in the scrubber and wet precipitator section are drained into a Dorr thickener. The heavy black slurry is drawn from the bottom of the settling tank, made into a dispersed slurry and sprayed into the dry fluffy black at the pelletizing machine. The wetted black thus joins the dry black again and is recovered. The water present in the slurry is evaporated from the wet pellets in the rotary drier. Fig. 6 shows from right to left the pelletizing building, the wet scrubber and wet precipitator, and the direct-contact gas-cooling tower.

Liquid Hydrocarbon Raw Materials for Furnace Carbon Black Manufacture

The raw material for furnace carbon black manufacture at Ellesmere Port can come either from petroleum or coal tar. In either case it is a carefully selected fraction for which fairly rigid specifications have been established. Carbon black raw material oils are of such nature as to be identified in general character and price with either heavy bunker oils or with distillate fuels such as are used in diesel or heating service. Often a suitable carbon black raw material is produced as a by-product of oil or coal-tar refining, and such oils can be used without further treatment. The economics of furnace carbon black manufacture are such as to demand a raw material at essentially the bunker-fuel price if a satisfactory rate of pay-out on investment is to be obtained. This is not to say, however, that any oil satisfactory for bunker fuel use or for diesel or heating use is a satisfactory furnace carbon black raw material. The art of making high-

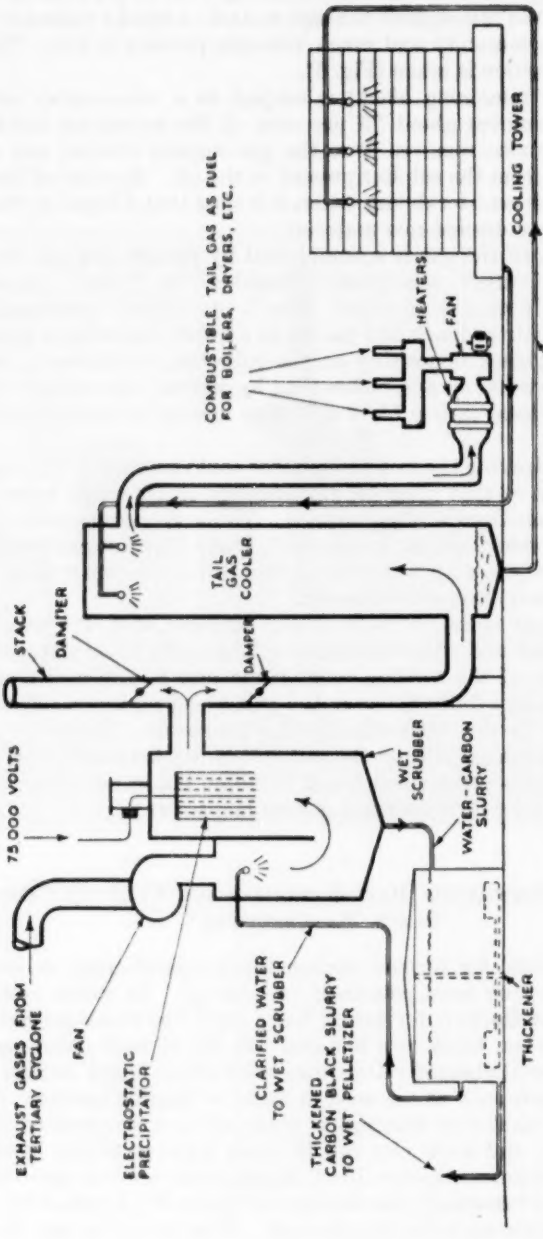

FIG. 5

TAIL-GAS SCRUBBER AND RECOVERY SYSTEM

quality furnace blacks for rubber from oil is in its early stages of development. Very slight changes in oil quality can make important changes in product quality, so that, at the present stage of development, carbon black quality considerations, rather than purely economic factors, dominate the selection of fuels for furnace carbon black manufacture. Continued intensive research can certainly be expected to extend somewhat the range of fuel qualities that will be acceptable.

More specifically it may be stated that a carbon black raw material oil should contain a maximum of aromatics and further should be :—

(1) Low in sulphur.
(2) Substantially free of suspended ash or carbon.
(3) Low in high-molecular-weight resins and asphaltenes.
(4) Substantially free of emulsified water.

If a process is used in which the fuel is vaporized before introduction to the furnace, the fuel should be substantially free of high-molecular-weight and/or unstable ends that would deposit carbon in the vaporizer or in the hot-transfer lines. If a process is used in which the fuel is atomized, the fuel should be low in light ends which might flash in the preheater and nozzle. Usually such a fuel will have a flash point of about 250° F or higher. It is quite important that the fuel be uniform from shipment to shipment or at least the fuel should be available in large lots so that sufficient tankage at the carbon black plant will permit operation for several months on the same fuel.

To satisfy the above requirements the fuel must be a distilled product if it comes from coal tar, or it must be free of virgin bottoms if it comes from petroleum. The products from vertical retort tar are usually on the lower side of the desired aromaticity, while those from coke-oven tar, *e.g.*, the anthracene oil fraction, may be so highly aromatic to require blending with less aromatic oils to give the proper carbon black quality. Suitable carbon black oils from petroleum result from catalytic or thermal cracking of gas oils. The aromatic cycle stocks from thermal cracking of virgin gas oils or thermal cracking of catalytic cycle stocks are used; likewise, the tars from these processes can be used. In some cases catalytic cycle stocks can be used without further cracking, particularly if the catalytic cracker feed stock is a highly naphthenic gas oil. In the U.S. one refinery operates two catalytic crackers in series, which produces in the second-stage unit a very aromatic cycle stock.

While it is true to a certain extent that the aromatic content of a fuel is important from an economic standpoint in that the aromatic content greatly influences the yield of black and the production rate from a given unit, it should again be emphasized that a high content of the proper kind of aromatics is absolutely essential to give the quality of carbon black required by the rubber compounder. Usually this is a matter of having the proper minimum aromatic content, but it is also possible to select fuels with such high aromatic content as to give blacks that are difficult to process in rubber. Close collaboration at the technical level is required between fuel supplier and carbon black producer in order to issue suitable fuel quality.

Conclusion

Although there are still many teething troubles, the 8000 to 10,000 tons planned capacity of the plant at Ellesmere Port should provide over one-fourth of the total carbon black required by the United Kingdom. At present the raw material is being produced by an American refinery. So far, successful commercial production by the process used at Ellesmere Port has been developed from only three specific refinery products; all three of these are American. But as more and more oil is produced in the Middle East it is evident that British fuel prices will become more economic, and a real necessity for saving dollars will probably exist for a long time to come. Clearly the objective should be to find suitable British raw materials in place of the American.

The particular petroleum or coal-tar products most likely to be available for future conversion into carbon black must be determined. After the choice of the best candidates is made the necessary development programme must be carried out, on pilot plants, in rubber laboratories, and by road test, to produce carbon blacks from British raw materials at least as good and as cheap as to-day's products. This work is already under way, but more time and money will be required.

As the many plans for new refineries and new processes come into reality, new materials will be available for test. With the progressive foresight and continued co-operation of the petroleum industry eventual success is certain.

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Discussion

Alan Speedy: Fig. 1 in the paper is a chart showing carbon black production in the U.S.A. from 1930 to date. I should like to carry your minds back to the days of 1913, when carbon black was very little used. At that time the late S. C. Mote, of the India Rubber, Gutta Percha, and Telegraph Works Company, at Silvertown, found that carbon black, when incorporated in rubber, gave excellent reinforcing properties; and when embodied in the treads of motor tyres amazing road performance resulted and their life was extended.

From then on carbon black sales began to soar, and I think that in the year 1918 the production figure for carbon black in America was of the order of 43 million lb. To-day you have seen that the production figure has reached the enormous height of about 1300 million lb per annum.

The authors have also made reference to the raw materials, but nothing has been said of the efficiency of the process. I am not referring to the means of dealing with that last 5 per cent of carbon particles, to prevent the sooting up of the countryside, but to the yield of black per gallon of oil. We know that the channel or impingement method produced 1 to 2 lb per thousand cu. ft. of natural gas burned. The production of lamp-black

is 3 to 4 lb per gallon of oil burned and the modern furnace plants in America, burning natural gas, yield, I believe, something of the order of 5 to 12 lb of black per thousand cu. ft. of natural gas burned, depending upon the quality of the black.

I would like to ask Mr Cabot and his colleagues what yield they can expect from the raw materials available here, whether there is any marked difference between using a coal tar distillate from high-temperature carbonization of coal as against low-temperature carbonization of coal, and whether they have any experience of the use of indigenous shale oils.

A few days ago I was discussing the oil-black process with a friend, and he wondered what effect water would have on the properties of the black. Water, in intimate contact with carbon-black particles, affects both the surface and adsorptive phenomena, and I would like to hear the authors' comments on the effect of water on the properties of the carbon black made at Ellesmere Port. My immediate reaction, of course, was that there would be hardly any effect.

MAJOR W. H. CADMAN : One outstanding matter, and one which appeals to me, is the care which has been taken to avoid a smoke nuisance in the vicinity of the plant. I am sure that if all the carbon black plants constructed in Great Britain deal with the problem in the same way there will be no cause for regret, from the point of view of the local inhabitants, in having these new industries starting up in their midst.

I would also like to ask if it is a fact that the quality of furnace carbon black from liquid hydrocarbons, especially from the point of view of compounding it with rubber, varies very much, and what is the relationship between yield and quality. If the highest quality black is required, does it mean very much sacrifice in respect of yield ? Or is it possible to ensure high yield and still maintain the quality ? In the early days it was considered that it would never be possible to obtain, by the furnace process, a black comparable in any way with channel black, particularly for compounding with natural rubber. But I can appreciate from what we have heard that those difficulties are being overcome, and that it will be possible in the near future to substitute furnace black for nearly all the purposes for which channel black was employed originally. I can see the production curve rising, and the time coming when the bulk of the carbon black used will be made by the furnace process from oil and tar which, as has been pointed out, is largely independent of the position of the source of raw materials.

Just how far that situation affects the rubber industry in Great Britain will be obvious when I recall that not many years ago that industry was almost on its last legs from the point of view of obtaining the carbon black that it required. Things became so serious that on one occasion bags of carbon black had to be shipped to the U.K. on the *Queen Mary* as deck cargo in order to keep the rubber industry going. On another occasion matters were so serious that a very poor-quality black made from anthracene and naphthalene in German plants had to be sent to Britain for use by the rubber industry. May that never occur again.

I can confirm Mr Speedy's remark that the first experiments on reinforcing the value of carbon black in rubber were made in Great Britain.

Another fact not generally known is that carbon black was being made in Great Britain by Reckitt's of Hull as early as 1908 and the plant continued in operation until 1933. Experimental work carried out by the Department of Scientific and Industrial Research at Teddington during the last war showed that it was possible to utilize various liquid hydrocarbons for carbon black manufacture, including petroleum and tar products; but for some reason this pioneer work was not made use of to manufacture carbon black from indigenous raw materials. It is interesting to note that Cabot Carbon Ltd. aim at finding suitable British raw materials.

J. S. PARKER : A suitable hydrocarbon is utilized for this process of carbon black manufacture, which is described as essentially a cracking operation with the heat required being supplied by a fraction of each gallon of the hydrocarbon entering the furnace. The term " a fraction " can mean anything. Could we have a more definite figure preferably as a percentage ?

The tail end of the Ellesmere Port plant is interesting, as it has been devised to reduce the carbon black content of the residual gas. This has been done for two reasons : (1) to meet the smoke regulations; and (2) because the estimated recovery of 90 per cent of the 5 per cent carbon black which would otherwise be lost is economic at prices ruling in Britain. If (2) is correct, then it is the major consideration and one need not inquire whether the extent of the capital outlay outlined was a necessity to secure (1).

The special hydrocarbons needed for this process are, because of their required cheapness and aromatic content, products which are most likely to have a high sulphur content. This sulphur results in the formation of SO_3 and SO_2 which travels through in the dry state to the tail-end additions, where it is met by a water spray. This water spray is for wetting the remaining carbon black ahead of the Cottrell precipitator and has nothing to do with the SO_3 and SO_2, but it must have a scrubbing action on these and take them down with it to the bottom of the tower. Thence the water as shown in the sketch is on a closed circuit back to the spray. Unless there is some neutralizing system which is not shown the condition of the water, after even a few days' operation, must be interesting.

MISS A. KENNEDY : Mr Cabot has said that one reason why Ellesmere Port was chosen as the site for the factory was that the factory is surrounded by refineries, and although he does not want anything from them at present, he might in the future. What will he want from the refineries ?

M. M. WILLIAMS : I notice that in the preparation of carbon black the need for having aromatic constituents in the raw materials is stressed. From what we saw in the film, the carbon black seemed to have a benzene-ring type of structure, which possibly due to its preparation may contain unsaturated bonds. This seems to be borne out by the fact that the volatile content has an influence on the properties of carbon black. I should like to ask whether such influence is a valence effect.

Can Mr Cabot elaborate a little more on the surface adsorption and the wettability properties the various carbon blacks have and what effects these physical properties have on rubbers, inks, etc., as distinct from other properties ?

H. C. LACK: I should be very glad if Mr Cabot could give us some information about the Lodge–Cottrell precipitation. I notice that 75,000 volts are on alternate plates, and the other plates are earthed. It seems to me that, with the finely divided carbon in the gases passing over, there are the conditions for flash-over, and I am wondering whether that is a trouble experienced in the operation of the plant.

D. L. SAMUEL: One of the things which impresses me is the cleanliness of plants making material that is frightfully difficult to remove.

We have been told about the manufacture of a "suitable" carbon black; presumably that means one that is suitable for incorporation in rubber. What sort of control tests are applied to the finished product to ensure that it is suitable? It would be possible to test by making up compounded rubber; but presumably there are some quite rapid control tests, and perhaps the authors will give an idea of what they are.

C. A. STOKES: A question was asked by Mr Speedy concerning the yields of the carbon black we are making at Ellesmere Port from the types of aromatic oils we are using; and he has given rather accurate figures for the yields of carbon blacks by various processes from various other fuels. I think it is fair to say that by our process, and that of our competitors building in England, something between 2 and 3 lb of carbon black are made from every gallon of liquid hydrocarbon consumed in the furnaces.

That yield is not so high as the yield of lamp-black, which Mr Speedy has told us is 3 to 4 lb per gallon of oil burned. But that lamp-black, compared with our standards of black for reinforcing rubber, is the size of paving-stones! The maintenance of the surface properties of carbon black is important.

That answers partly the question put by Major Cadman.

Then Mr Speedy asked about the use of low-temperature as compared with high-temperature coal-tar-distillation products. In general, we can say that high-temperature or coke-oven coal tar, when distilled, produces distillate fractions which would be very much better for making carbon blacks, since they are more aromatic. If they are too aromatic they can be blended back to the desired level. On the other hand, the process of low-temperature carbonization, particularly the truly low-temperature carbonization, which is little practised in England, produces coal tar which is not sufficiently aromatic, nor are the distillates sufficiently aromatic to give good yields of carbon black. Some of the coal tars are intermediate and will produce distillates which I am sure will be suitable.

We have had very little experience with shale-oil distillates, and such experience as we have had would indicate that, as distilled by any known process to date, they are not sufficiently aromatic to be usable. Our experience has indicated also that they are apt to be rather dirty oils, containing suspended ash or shales and carbon. But I think that, if the shale-oil industry ever develops to the stage at which its products are subsequently refined, there is no reason why the refined cracked products should not be as suitable as ordinary cracked petroleum oils.

With regard to the influence of water on the properties of carbon black, water is certainly important in our process, but it is not essential. We could

practise air-cooling if it were convenient to do so, but it is more convenient to use water cooling. The presence of salts and alkalis in water has no significant effect on the properties of carbon black. We have investigated this matter, but the means of detecting the difference are not good enough to find it generally. The presence of suspended, or rather dissolved, salts in the water does increase somewhat the pH of carbon black. If a slurry is made of furnace black cooled with water and its pH measured in the laboratory, there will be slightly higher values, of 8 to 9; but values as high as 8 will be obtained for furnace blacks which are air-cooled. It is in the range below 7 that the pH of carbon black becomes an important factor in subsequent use. Channel black has a pH of between 4 and 5, and at that level it has a retarding effect on the accelerators used in rubber compounding.

The quality of carbon black has a very important effect on yield. If high-quality blacks are made, the yield will be lower than if the blacks are of lower quality. In general, the finer the particle size the lower is the yield. There is every reason to believe that this difference in yield can be minimized by further research, which will take time.

Some comment has been made on the difference between the furnace and channel qualities of carbon black. We now feel that furnace blacks made from liquid hydrocarbons are better than channel blacks for reinforcing rubber, when used properly, and I think that before long that view will be universal. I think that is largely because furnace black is made and taken out of the atmosphere very rapidly, without contact with excess oxygen, and it has a more nascent or active surface.

The production rate of a plant is almost as important as the yield from the raw material. One of the troubles with the carbon black industry is that so much capital is wrapped up with steel and brick in order to get a little soot; and when a 6 per cent yield is obtained from natural gas and then another 3 per cent thrown away into the air, the steel has to be cheap and the cost of the labour engaged in putting it up must be even cheaper. The furnace black process may yield 2 to 3 lb of black per gallon of oil used, which is perhaps 30 or 40 per cent of the carbon in the oil. In addition, only 30 to 40 per cent of the air needed for perfect combustion is used, so that the volume of flue products is very small. In the channel process, some twenty, if not 100 times, the amount of air needed for perfect combustion passes through one of our hot buildings, and it would be a tremendous project to recover the smoke.

The Germans have developed a channel process based on the use of liquid hydrocarbons, and they get high yields because of the rather high content of aromatics in their raw material. They filter the exhaust gas as it is diluted to something within reason—a dilution of 5 to 10 times the theoretical air for combustion.

In Germany recently I was impressed by the fact that the developers of the German carbon black process stressed how sorry they were that our bombers missed their carbon black plant almost completely; they knew they had lost the war and they said that, by keeping the war going for another year and a half with the aid of their carbon black output, they lost a few more cities!

Mr Parker asked about the relative amounts of heat used for cracking

the oil for the carbon product *versus* the heat represented in the carbon itself; and he did not say, though he could have said, the heat " wasted." I do not recall exact figures, but I think that probably, if a careful heat balance is made on a carbon black process, assuming that it is followed by perfect heat exchangers and that all sensible heat is recovered, it will be found that no more than 5 per cent of the heating value of the oil is actually required to decompose the oil molecules. In actual practice a 20 to 40 per cent yield of carbon is obtained; so that we are literally throwing away 60 to 80 per cent of the heat in a gallon of oil. But this will not go on for ever; it is a matter of capital expenditure and research on finding out how to keep heat exchanger tubes clean. Later on, as costs increase, the carbon black industry will recover substantial amounts of sensible heat and will use it to generate power. Further, we do not now recover all our flue gas, but we do recover a portion of it.

The question concerning sulphur disposition is very interesting. As a matter of fact, if we bubble SO_2 and SO_3 into water indefinitely, the water becomes very acid! We have found also that, if we pump that water through an ordinary steel pipe which is fastened together with brass valves at intervals, we have to run frequently to and from the pipe shed to obtain fresh valves to prevent the pipe leaking.

These difficulties arise, I think, because engineers who have been out of school for a few years become obsessed with the notion that the only thing that counts is experience, and they forget absolutely all that they learned in chemistry.

But when making carbon black there is not more than a trace of sulphur oxides in the flue gases. In the early days of our plant, when we began to worry about how much sulphur oxides we should make, we wanted to reassure ourselves that our thermodynamic predictions were justified, and in Liverpool University Library we found that the British had invented a good process for recovering sulphur, consisting of contacting SO_2 with carbon at a suitably high temperature. Our temperature is even above the range recommended. The result is that there are very few sulphur oxides in our exhaust system; there is some hydrogen sulphide and probably some COS.

We were asked by Miss Kennedy what product we wanted from the refineries in the Ellesmere Port area. We should like a highly cracked product formed from the vapour-phase cracking of gas oil or naphtha. For example, we feel that such operations as are being practised in Manchester, and also at Stanlow, will eventually produce products which are fairly close to our needs.

A question was asked by Mr Williams concerning the surface characteristics of carbon blacks and what are the surface differences. It would seem that in the main there are really two kinds of surface differences of considerable importance. First, there are those surface differences associated with the amount of burning of the surface which has occurred by reason of oxygen or oxidizing gases, and which also extends the surface. Secondly, there are the surface differences which manifest themselves in intense flocculation of the particles, something which we in America have called " structure "; in other words, some carbon black particles, either in the process of their formation or shortly thereafter, seem to have an

intense liking for neighbouring particles, and they form chains of particles which stick together rather well. These high-structure blacks are characterized by extremely low density, of about 2 lb/cu. ft. They are rather inclined to disperse in rubber to give a higher viscosity mix; and the same can be said about their use in ink. We believe that these blacks, when properly compounded, will give the best results in tyres of any blacks to date. If they are allowed to remain at high temperature in the presence of oxidizing gases, a great deal of etching of the surface occurs, and the attachment of some atoms of oxygen, tending to produce a less useful black in a non-polar vehicle but perhaps a more useful black in a polar vehicle. Similarly, these oxidizing effects produce a low pH black, having a retarding effect in the accelerators and in rubber.

The question by Mr Lack was interesting, as to whether there are flash-over troubles in the Lodge–Cottrell precipitators as the result of putting 75,000 volts across a field of carbon black particles suspended in gas. Very definitely we have those troubles when we least expect them, although we should have expected them. We have collected particles from gas in Lodge–Cottrell precipitators for years in the U.S. and have experienced very little trouble. But when we began to make furnace blacks of high structure from oil, which blacks have the tendency to form chain-like agglomerates, we could not get the load on the Lodge–Cottrell; the current leakage across was so great that the amperage protector on the Lodge–Cottrell would kick out from time to time. Thus, we had to take the black through the Lodge–Cottrell faster, or distribute it more, or dilute it somewhat. When all these precautions are taken, it is relatively easy to put a rather conductive material through the Lodge–Cottrell and get highly effective agglomeration.

We have done a lot of work on the use of sonic energy in dealing with carbon black aerosols. Its effectiveness is not dependent on the electrical conductivity of the black. The performance of a Lodge–Cottrell is also influenced greatly by very small traces of tarry matter left on the black; it has an effect on the collectability and agglomeration of black. I cannot explain it, but it is there, and it is very important.

The final question was that by Mr Samuel concerning our control tests for the rapid determination of quality. These control tests are based largely on a quick test for particle size. If we are using a given fuel and process, we know that we are making the right type of black; there is no question about that. Thus, all that we have to determine in a hurry is whether or not we are right in respect of particle size; and by an empirical test, such as the reflection of light from a mixture of carbon black and oil, we have a very useful control.

We have also developed a machine called the "negrometer," which measures the light reflected from carbon-black-in-oil dispersions. We also use the tinting-strength test, which is a back-handed way of getting at particle size. We have a test of hiding power, a test on the density of the pelletized black, which may be determined in a matter of seconds; and a test of the moisture content of the dried pellets, which can be determined within minutes.

Vote of Thanks

THE PRESIDENT: Now I have the very pleasant duty of thanking, on your behalf and my own, Mr Cabot and his associates, Mr Edminster and Mr Stokes, for having given us a most excellent evening, for having shown us the film, which is one of the most remarkable industrial films I have ever seen, for having outlined their manufacturing process and discussed the technical problems and, rather unusually, for answering every single question put to them.

I would like you all to join me in expressing thanks to these gentlemen.

(The vote of thanks was accorded with enthusiasm.)

Communicated Discussion

E. A. SMITH wrote: Information was sought by a speaker on how one evaluated a carbon black with respect to its suitability for its various applications. Mr Stokes, perhaps wisely, explained that the suitability was determined by experience and that his company controlled the quality of a black which they knew to be suitable, by certain routine laboratory tests.

More information on the suitability of a black for rubber reinforcement, which is a major application, is given by G. L. Clark and J. Fuchs of the University of Illinois in their Technical Report, dated 5 June 1950, for the Office of Rubber Reserve, U.S.A., entitled "Structural studies of new reinforcing blacks for low-temperature elastomers." Using X-ray diffraction, electron microscope, B.E.T. adsorption technique, iodine and oil values, they have graded seven commercial carbon blacks used widely.

Their results are of outstanding importance. They find that the relative abrasion resistance of a black is related to the ratio of the width to depth in the primary crystallite. The higher the La/Lc ratio, the better the abrasion resistance of the black in rubber. In this, one is provided with an optical or structural yardstick for measuring quality.

Mandel, Stiehler, and Steel (Progress Report No. 3, to the Office of Rubber Reserve) have already reported that the abrasion resistance of tyres is related to shelf-life. Clark and Fuchs provide the next clue in reporting that the La/Lc ratio in blacks decreases with time over a year or more. These two facts can be ready in conjunction with one another.

The difference between carbon black and graphite was touched upon by the authors of this paper. For the benefit of those members, who have not the time to delve further into this subject, but are, nevertheless, puzzled by the difference, the following remarks are added. Both carbon black and graphite are made up of carbon atoms arranged in hexagons which, in turn, are arranged in parallel sheets. In the two products the sheets are differently spaced; in blacks, they are 3·67 to 3·70 Å apart, depending on the type of black. The spacing in graphite varies between 3·35 and 3·42 Å. This difference in the distance apart of the sheets is important, bringing with it different physical and chemical properties.

But the essential difference is that whereas in blacks the parallel sheets are out of register with respect to each other, in graphite the alternate sheets are both parallel and in register. Imagine a stack of playing-cards,

in which each card represents a sheet of atoms. If the stack is now skewed around by pressing and twisting it, the cards will still be parallel, but they will be out of register. This random arrangement of the cards represents carbon black. If now we push *alternate* cards out a small measured distance but otherwise leave them with their edges still parallel, such an arrangement would represent graphite.

A third difference between the two products lies in the sizes of the primary crystallites, that is, in the sizes of the smallest crystalline units, which go to make up a visible particle. In blacks the diameter of the crystallite is around 300 Å or 30 millimicrons, whereas in graphite it will be much larger. In the electron microscope, the blacks are revealed as particles tending towards a spherical shape, while these are often arranged as chains. If one examines the finest graphite powder in the electron microscope, the particles are generally discrete, and show a distinct plate-like form.

From the above differences, emerge different physical and chemical properties. Thus graphite is lubricating to a high degree, and in the colloidal form is used widely in oil to reinforce lubrication.

In reply to Mr Smith the authors wrote : We are investigating some of the X-ray-defraction methods of evaluating carbon blacks, but do not wholly accept the conclusions of Clark and Fuchs just yet. We do not find sufficient evidence that the La/Lc ratio in blacks decreases measurably in finite periods of time such as a year or two. The fact that abrasion resistance of tyres is related to shelf-life is probably entirely due to the age of the rubber, rather than to any change in the carbon black.

DETERMINATION OF THE RING AND BALL SOFTENING POINT OF ASPHALTIC BITUMENS WITH AND WITHOUT STIRRING

By C. J. Krom * †

Summary

In the determination of the softening point of asphaltic bitumen (Ring and Ball Method) according to I.P. 58/44, mechanical stirring in the bath is prescribed, which is not the case in the normal A.S.T.M. method D36-26. The present investigation shows that stirring the bath reduces the R. and B. softening point for all bitumens by 1·6° C, both in the case of determinations in the water-bath and in the glycerine-bath, and consequently, if stirring were generally applied, it would involve alterations in all specifications with R. and B. limits.

Statistical calculations have shown that the repeatability (one operator and one apparatus) of the R. and B. determinations with stirring is not better than that of the determinations without stirring.

The conclusion can therefore be drawn that there is no reason for stirring the bath during the determination of R. and B. softening point.

Introduction

The determination of the R. and B. softening point according to the I.P. was, up to 1944, chiefly based on A.S.T.M. D36-26 supplemented, for conical rings and ball-centring device, from A.S.T.M. method E28-36 T, which, however, is mainly used for R. and B. determinations of substances other than asphaltic bitumen. The E-committee of the A.S.T.M. introduced stirring in the bath in their method E28-42 T, which has also been adopted in the I.P. 58/44 method. In order to obtain accurate knowledge of the differences in the R. and B. softening points obtained with and without stirring, a careful study was made of this question.

Procedure

All factors (except stirring) which may cause a difference in R. and B. temperature—viz. :

(1) pretreatment of the bitumen,
(2) difference of apparatus and thermometers,
(3) personal errors,
(4) difference in heating up rate

—were eliminated as far as possible. To this end the following measures were taken.

1. Each series of rings was filled with bitumen similarly pretreated.

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† Statistical calculations were made in co-operation with C. v. d. Poel and J. A. v. d. Heiden. The experimental work was carried out by J. S. Swart, while P. W. Oudhaarlem gave valuable assistance in making the many numerical calculations.

Some of the rings were used for the determinations without stirring and some for those with stirring.

2. All the determinations without stirring were carried out in the same apparatus; all the determinations with stirring in an identical apparatus with a stirrer. All the thermometers used were accurately calibrated one against the other.

3. All the determinations were carried out by the same skilled operator.

4. In order to level out, as far as possible, the influence of differences in heating-up rate on the mean value of a series, all determinations were made in pairs of different series.

Factors which may affect the difference between R. and B. softening point with and without stirring of different samples are :—

(1) the R. and B. temperature itself;
(2) the nature and origin of the bitumen (*e.g.*, wax content);
(3) the medium in which the determination is carried out (water or glycerine).

Therefore a number of bitumens of different origins and paraffin-wax contents (ranging from 0·5 to 5 per cent wt) with R. and B. softening points between 30° and 170° C, were investigated.

Experimental Results

For the determinations without stirring the normal dual unit as prescribed in the I.P. method was used. For those with stirring a stirrer was fitted in a dual unit, as shown in Fig. 1.

The complete assembly is shown in Fig. 2. A governor in the form of a disc on the shaft of the motor (the speed of which is adjustable) serves to keep the number of revolutions constant. The rubber tube connexion minimizes vibration of the apparatus. It was found that at more than 100 revolutions per minute of the stirrer the R. and B. softening point is no longer dependent on the number of revolutions. An excessive number of revolutions, however, causes vibration of the apparatus. For this reason the number of revolutions was kept between 150 and 200 per minute during the experiments.*

Tables I and II show the results of the determinations with and without stirring. The tables have been subdivided into parts relating to determinations in a water- and in a glycerine-bath. Of each series of determinations —both with and without stirring—the " arithmetic mean " was determined.

The tables show for a few cases the influence of the pretreatment. The series 2, 3, and 4 and also the series 16, 17, and 18 were all carried out within the limits of the standardized method. Especially in series 18, where the

* *Note by C. F. Jackson.* Dimensions of the apparatus employed are known, from other investigations, to be critical in tests carried out by this method. Throughout his work, the author used a squat 600-ml beaker, 12 cm deep and 8·5 cm in internal diameter. The dimensions of the holder were as shown in I.P. 58/46, Fig. 2*b*. The base plate had the same outside dimensions as the ring-holder and was 2 cm from the bottom of the vessel. The vessel was heated by an electrical hot-plate and the liquid stirred at a rate of 150–200 r.p.m. using a small blade stirrer about 5 cm in diameter.

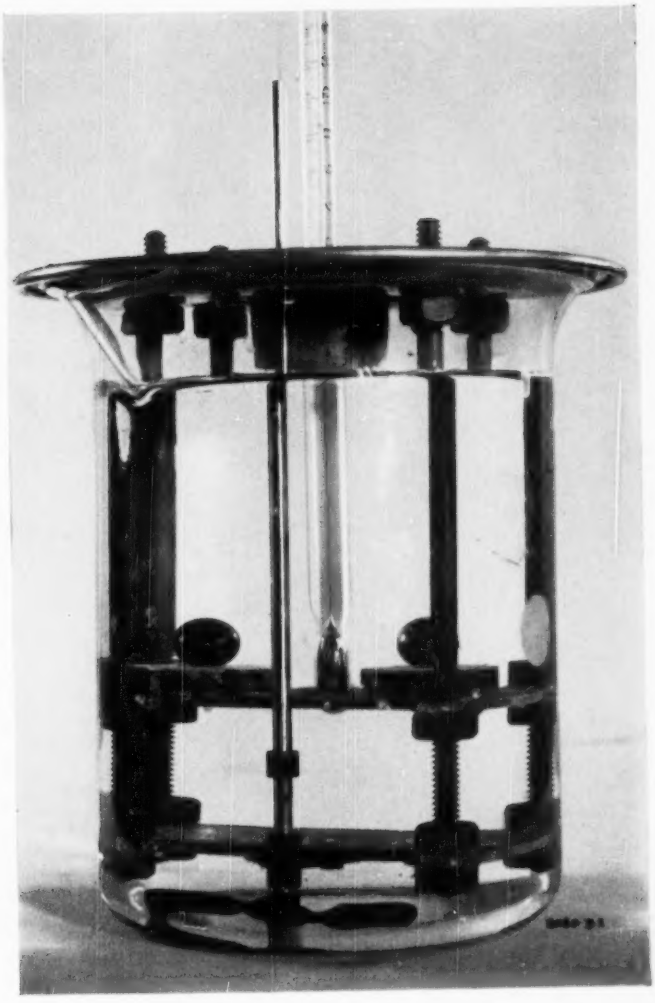

FIG. 1

RING AND BALL APPARATUS WITH STIRRER

(*To face p. 728.*

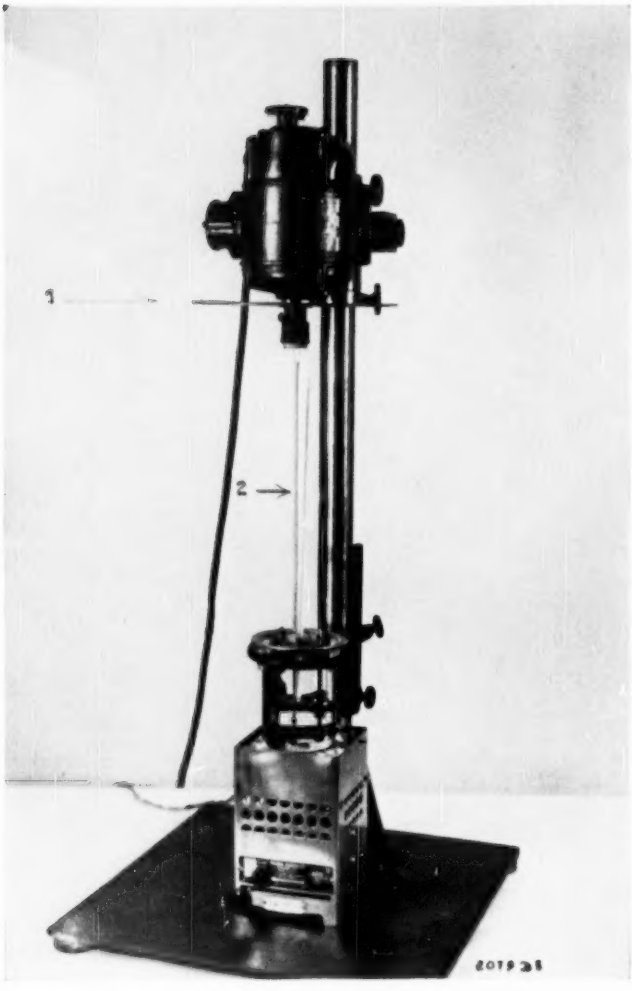

FIG. 2

RING AND BALL APPARATUS WITH STIRRER

1. Disc.
2. Rubber tubing.

pretreatment was continued till the sample was absolutely air-free, the sample has hardened considerably.

The results were treated statistically.

TABLE I

Ring and Ball Softening Point without Stirring

Asphaltic bitumen	Penetration	R. and B. softening point in ° C of separate determinations					Arithmetic mean ° C $\bar{X}_1$	Series no.
		x_1	x_2	x_3	x_4	x_5		
		Determinations in water-bath						
Mexican .	330/370	33·4	33·7	34·0	34·2	—	33·83	1
Venezuelan .	280/320	35·2	35·6	—	—	—	35·40	2
Venezuelan .	280/320	34·8	34·9	34·9	35·6	—	35·05	3
Venezuelan .	280/320	34·2	34·4	34·5	34·7	34·6	34·48	4
Middle East .	280/320	35·7	35·7	35·8	35·8	—	35·75	5
Venezuelan .	180/200	39·5	39·5	—	—	—	39·50	6
Mexican .	180/200	40·2	40·0	40·6	39·7	—	40·13	7
Egyptian .	180/200	44·2	44·4	45·0	—	—	44·53	8
Venezuelan .	80/100	46·6	46·6	46·4	—	—	46·53	9
Egyptian .	80/100	48·9	49·3	49·3	—	—	49·17	10
Venezuelan .	50/60	51·6	51·7	—	—	—	51·65	11
Mexican .	50/60	54·2	54·7	54·5	54·3	—	54·43	12
Mexican .	20/30	63·2	63·1	63·2	—	—	63·17	13
Venezuelan .	10/20	69·0	68·5	68·3	—	—	68·60	14
		Determinations in glycerine bath						
Venezuelan blown .		88·0	87·5	87·1	—	—	87·53	15
Venezuelan blown .		103·0	101·8	102·2	—	—	102·33	16
Venezuelan blown .		103·5	103·5	103·5	—	—	103·50	17
Venezuelan blown .		111·5	111·3	—	—	—	111·40	18
Venezuelan butane .		113·0	113·0	—	—	—	113·00	19
Venezuelan butane .		114·0	—	—	—	—	114·00	20
Venezuelan hard . .		116·5	116·7	117·0	—	—	116·73	21
Venezuelan blown . .		118·5	119·9	121·0	119·8	—	119·80	22
Venezuelan blown . .		124·9	125·2	—	—	—	125·05	23
Venezuelan blown . .		138·8	138·8	140·6	138·2	—	139·10	24
Venezuelan blown . .		146·2	145·8	—	—	—	146·00	25
Venezuelan butane .		167·0	169·2	—	—	—	168·10	26

STATISTICAL TREATMENT OF THE FIGURES

(a) *Statistical Theory Used*

A distribution curve can be plotted of the results of an infinite number of measurements of a certain quantity. If no systematic errors are assumed the maximum of this curve represents the correct value μ of this quantity. The standard deviation σ then gives a measure of the spread of the individual measurements.

Assuming a series of n measurements, which are indicated by x_1, x_2 . . . x_n, the arithmetic means $\bar{X}$

$$\bar{X} = \frac{\Sigma_i x_i}{n}$$

is the best approximation to the value μ.

TABLE II

Ring and Ball Softening Point with Stirring

Asphaltic bitumen	Penetration	R. and B. softening point in ° C of separate determinations					Arithmetic mean ° C $\bar{X}_2$	Series no.
		x_1	x_2	x_3	x_4	x_5		
		Determinations in water-bath						
Mexican	330/370	32·5	32·4	32·0	32·2	—	32·28	1
Venezuelan	280/320	32·7	32·7	—	—	—	32·70	2
Venezuelan	280/320	33·8	33·9	33·4	33·4	—	33·63	3
Venezuelan	280/320	33·5	33·5	32·8	32·8	32·8	33·08	4
Middle East	280/320	35·0	34·8	34·5	34·5	—	34·70	5
Venezuelan	180/200	37·3	37·3	—	—	—	37·30	6
Mexican	180/200	38·8	38·7	38·7	—	—	38·73	7
Egyptian	180/200	42·3	42·3	42·7	—	—	42·43	8
Venezuelan	80/100	45·2	45·2	—	—	—	45·20	9
Egyptian	80/100	46·6	47·2	47·3	—	—	47·03	10
Venezuelan	50/60	50·2	50·0	—	—	—	50·10	11
Mexican	50/60	52·8	52·8	52·8	—	—	52·80	12
Mexican	20/30	62·0	62·0	62·3	—	—	62·10	13
Venezuelan	10/20	67·0	67·2	—	—	—	67·10	14
		Determinations in glycerine bath						
Venezuelan blown		85·5	85·3	—	—	—	85·40	15
Venezuelan blown		101·7	101·4	101·6	102·0	—	101·68	16
Venezuelan blown		102·9	102·5	103·5	103·1	—	103·00	17
Venezuelan blown		110·0	110·2	110·3	—	—	110·17	18
Venezuelan butane		111·8	111·8	—	—	—	111·80	19
Venezuelan butane		112·8	112·8	—	—	—	112·80	20
Venezuelan hard		115·0	115·0	114·8	—	—	114·93	21
Venezuelan blown		117·0	118·0	118·6	119·4	—	118·25	22
Venezuelan blown		122·4	122·4	—	—	—	122·40	23
Venezuelan blown		136·4	138·4	137·5	136·8	—	137·28	24
Venezuelan blown		144·6	144·8	—	—	—	144·70	25
Venezuelan butane		165·0	166·0	—	—	—	165·50	26

The best approximation of the standard deviation is S. S^2 called variance is given by

$$S^2 = \frac{\Sigma_i (x_i - \bar{X})^2}{n - 1}.$$

Substitution of $\bar{X}$ by $\frac{\Sigma_i x_i}{n}$ gives

$$S^2 = \frac{\Sigma_i x_i^2 - \frac{(\Sigma_i x_i)^2}{n}}{n - 1}.$$

In the case of k series of n measurements (for k different samples) the formula for S^2 becomes

$$S_0^2 = \frac{\Sigma\left(\Sigma_i x_i^2 - \frac{(\Sigma_i x_i)^2}{n}\right)}{\Sigma n - k}$$

in which S_0^2 is now the variance due to error for the whole group.

The best approximation to the standard deviation of the mean with respect to μ is m.

$$m = \sqrt{\frac{s^2}{n}} = \sqrt{\frac{\Sigma_i x_i^2 - \frac{(\Sigma_i x_i)^2}{n}}{n(n-1)}}.$$

According to " Student " [1, p. 57, and 4] the error, so the difference between $\bar{X}$ and μ lies within a certain interval, depending upon the certainty required and the number of measurements, namely

$$(\bar{X} - \mu) < gm$$

in which g is a function of n and the required certainty, gm *is the confidence interval for a chosen certainty.* For a certainty of 99 per cent and $n \to \sim g \to 2{\cdot}57$.

In actual practice the concept " repeatability " is often used. Generally the repeatability of a method of measurement is defined as three times the standard deviation of one observation, calculated from the results obtained by one observer with one apparatus. In this case the chance of the difference between a duplicate determination being greater than the repeatability is 1 in 20.

To ascertain whether the variances due to error found show real differences, an analysis of variance must be made. For comparison of several variances Bartlett's test [1, p. 123 and 2] was used and for comparison of two variances the F-test.[1, p. 62, and 2, p. 36]

Bartlett's test says that B/C is distributed as χ^2 with $l - 1$ degrees of freedom if l denotes the number of variances compared.

$$B = [\Sigma(\Sigma n - k)] \ln S^2 - \Sigma(\Sigma n - k) \ln S_i^2$$

$$C = 1 + \frac{1}{3(l-1)}\left[\Sigma\left(\frac{1}{\Sigma n - k}\right) - \frac{1}{\Sigma(\Sigma n - k)}\right]$$

S^2 is a pooled variance obtained by pooling S_i^2.

The level of significance can be read from a χ^2 table.[1, page 268, and 2, Table II]

F is defined as the ratio of the larger variance to the smaller. Attached to the variance ratio are two sets of degrees of freedom, viz., $(\Sigma_n - k)_1$ for the larger variance and $(\Sigma n - k)_2$ for the smaller. The significance level can be read from an F table.[3 Table V, and 2, Table III]

(b) *Statistical Treatment of the Figures Obtained*

The quantities relating to the R. and B. determinations without stirring were given the Index 1 and those with stirring the Index 2. The Tables III and IV contain various quantities calculated from determinations with and without stirring.

The tables do not show the S values of the softening-point determinations for the same bath liquid to be a function either of the softening point temperature itself or of the wax content of the bitumen. It was remarkable, however, that the determinations in the glycerine bath gave, in general, higher S values than those in the water-bath. For the calculation

of the standard deviation of the two methods we may, therefore, classify all the determinations into four groups, namely :—

(1) determinations without stirring in the water-bath;
(2) " " " " " glycerine-bath;
(3) " with " " " water-bath;
(4) " " " " " glycerine-bath.

TABLE III

Statistical Calculations

R. and B. softening point without stirring

Series no.	n	Σx^2	Σx	$(\Sigma x)^2$	$\frac{(\Sigma x)^2}{n}$	$\Sigma x^2 - \frac{(\Sigma x)^2}{n}$	S_1^2	S_1	$m_1 = \sqrt{\frac{S_1^2}{n}}$
	Determinations in water-bath								
1	4	4,576·89	135·3	18,306·09	4,576·52	0·37	0·123	0·35	0·14
2	2	2,506·40	70·8	5,012·64	2,506·32	0·08	0·080	0·28	0·19
3	4	4,914·42	140·2	19,656·04	4,914·01	0·41	0·137	0·37	0·14
4	5	5,944·50	172·4	29,721·76	5,944·35	0·15	0·037	0·19	0·12
5	4	5,112·26	143·0	20,449·00	5,112·25	0·01	0·003	0·06	0·14
6	2	3,120·50	79·0	6,241·00	2,120·50	0·00	0·000	0·00	0·19
7	4	6,440·49	160·5	25,760·25	6,440·06	0·43	0·143	0·38	0·14
8	3	5,950·00	133·6	17,848·96	5,949·65	0·35	0·173	0·42	0·16
9	3	6,496·08	139·6	19,488·16	6,496·05	0·03	0·013	0·12	0·16
10	3	7,252·19	147·5	21,756·25	7,252·08	0·11	0·053	0·23	0·16
11	2	5,335·45	103·3	10,670·89	5,335·45	0·00	0·005	0·07	0·19
12	4	11,848·47	217·7	47,393·29	11,848·32	0·15	0·049	0·22	0·14
13	2	11,970·09	189·5	35,910·25	11,970·08	0·01	0·003	0·06	0·16
14	3	14,118·14	205·8	42,353·64	14,117·88	0·26	0·130	0·36	0·16
$\Sigma n = 46$ $\Sigma n - k = 32$				$\Sigma\left(\Sigma x^2 - \frac{(\Sigma x)^2}{n}\right) = 2·36$			$S_0^2 = 0·0738$	$(S_0 = 0·27)$	
	Determinations in glycerine-bath								
15	3	22,986·66	262·6	68,958·76	22,986·25	0·41	0·203	0·45	0·42
16	3	31,417·08	307·0	94,249·00	31,416·33	0·75	0·373	0·61	0·42
17	3	32,136·75	310·5	96,410·25	32,136·75	0·00	0·000	0·00	0·42
18	2	24,819·94	222·8	49,639·84	24,819·92	0·02	0·020	0·14	0·52
19	2	25,538·00	226·0	51,076·00	25,538·00	0·00	0·000	0·00	0·52
20	1	12,996·00	114·0	12,996·00	12,996·00	0·00	—	—	0·73
21	3	40,880·14	350·2	122,640·04	40,880·01	0·13	0·063	0·25	0·42
22	4	57,411·30	479·2	229,632·64	57,408·16	3·14	1·047	1·02	0·37
23	3	31,275·05	250·1	62,550·01	31,275·01	0·04	0·045	0·21	0·52
24	4	77,398·48	556·4	309,580·96	77,395·24	3·23	1·080	1·04	0·37
25	2	42,632·08	292·0	85,264·00	42,632·00	0·08	0·080	0·28	0·52
26	2	56,517·64	336·2	113,030·44	56,515·22	2·42	2·420	1·56	0·52
$\Sigma n = 31$ $\Sigma n - k = 19$				$\Sigma\left(\Sigma x^2 - \frac{(\Sigma x)^2}{n}\right) = 10·22$			$S_0^2 = 0·5379$	$(S_0 = 0·73)$	

Tables III and IV give the calculation of the mean standard deviation S_0 for each group.

Mean Standard Deviation S_0 *in* ° *C*

	R. and B. without stirring	R. and B. with stirring
In water-bath . . .	0·27	0·24
In glycerine-bath . .	0·73	0·55

TABLE IV

Statistical Calculations

R. and B. softening point with stirring

Series no.	n	Σx^2	Σx	$(\Sigma x)^2$	$\frac{(\Sigma x)^2}{n}$	$\Sigma x^2 - \frac{(\Sigma x)^2}{n}$	S_0^2	S_0	$m_0 = \sqrt{\frac{S_0^2}{n}}$
	Determinations in water-bath								
1	4	4,166·85	129·1	16,666·81	4,166·70	0·15	0·049	0·22	0·12
2	2	2,138·58	65·4	4,277·16	2,138·58	0·00	0·000	0·00	0·17
3	4	4,522·77	134·5	18,090·25	4,522·56	0·21	0·069	0·26	0·12
4	5	5,492·02	165·4	27,357·16	5,471·43	0·59	0·147	0·38	0·11
5	4	4,816·54	138·8	19,265·44	4,816·36	0·18	0·060	0·24	0·12
6	2	2,782·58	74·6	5,565·16	2,782·58	0·00	0·000	0·00	0·17
7	3	4,500·82	116·2	13,502·44	4,500·81	0·01	0·003	0·06	0·14
8	3	5,401·87	127·3	16,205·29	5,401·76	0·11	0·053	0·23	0·14
9	2	4,086·08	90·4	8,172·16	4,086·08	0·00	0·000	0·00	0·17
10	3	6,636·69	141·1	19,909·21	6,636·40	0·29	0·143	0·38	0·14
11	2	5,020·04	100·2	10,040·04	5,020·02	0·02	0·020	0·14	0·17
12	3	8,363·52	158·4	25,090·56	8,363·52	0·00	0·000	0·00	0·14
13	3	11,569·29	186·3	34,707·69	11,569·23	0·06	0·030	0·17	0·14
14	2	9,004·84	134·2	18,009·64	9,004·82	0·02	0·020	0·14	0·17
$\Sigma n = 42$ $\Sigma n - k = 28$					$\Sigma\left(\Sigma x^2 - \frac{(\Sigma x)^2}{n}\right) = 1·64$		$S_0^2 = 0·0586$	$(S_0 = 0·24)$	
	Determinations in glycerine-bath								
15	2	14,586·34	170·8	29,172·64	14,586·32	0·02	0·020	0·14	0·39
16	4	41,351·41	406·7	165,404·89	41,351·22	0·19	0·063	0·25	0·28
17	4	42,436·52	412·0	169,744·00	42,436·00	0·52	0·173	0·42	0·28
18	3	36,410·13	330·5	109,230·25	36,410·08	0·05	0·025	0·15	0·32
19	2	24,998·48	223·6	49,996·96	24,998·48	0·00	0·000	0·00	0·39
20	2	25,447·68	225·6	50,895·36	25,447·68	0·00	0·000	0·00	0·39
21	3	39,629·04	344·8	118,887·04	39,629·01	0·03	0·013	0·12	0·32
22	4	55,935·32	473·0	223,729·00	55,932·25	3·07	1·023	1·01	0·28
23	2	29,963·52	244·8	59,927·04	29,963·52	0·00	0·000	0·00	0·39
24	4	75,380·01	549·1	301,510·81	75,377·70	2·31	0·769	0·88	0·28
25	2	41,876·20	289·4	83,752·36	41,876·18	0·02	0·020	0·14	0·39
26	2	54,781·00	331·0	109,561·00	54,780·50	0·50	0·500	0·71	0·39
$\Sigma n = 34$ $\Sigma n - k = 22$					$\Sigma\left(\Sigma x^2 - \frac{(\Sigma x)^2}{n}\right) = 6·71$		$S_0^2 = 0·3050$	$(S_0 = 0·55)$	

So there seems to be very little difference in accuracy between determinations without and with stirring in the water-bath and slightly more difference between those in the glycerine-bath.

Barlett's test shows that there is more than 99·9 per cent certainty that each of the four variances due to error will actually differ from the other three (Table V).

From the F-test (Table V) we learn that there is more than 99·9 per cent certainty that there are differences in variance due to error (S_0^2) between the determinations in water and in glycerine, whether stirring is applied or not. It is improbable that the differences in S_0^2 due to stirring or no stirring are significant.

Consequently, the R. and B. determination with stirring is not appreciably more accurate than that without stirring.

Table VI gives for each series the difference in softening point with and without stirring and also for the case of 99 per cent certainty the confidence

interval for this difference. The results have been plotted in Fig. 3 as a function of the R. and B. temperature. This graph shows that :—

(1) The confidence interval intersects the 0 axis only in some cases, all of which are determinations in the glycerine bath. There is thus

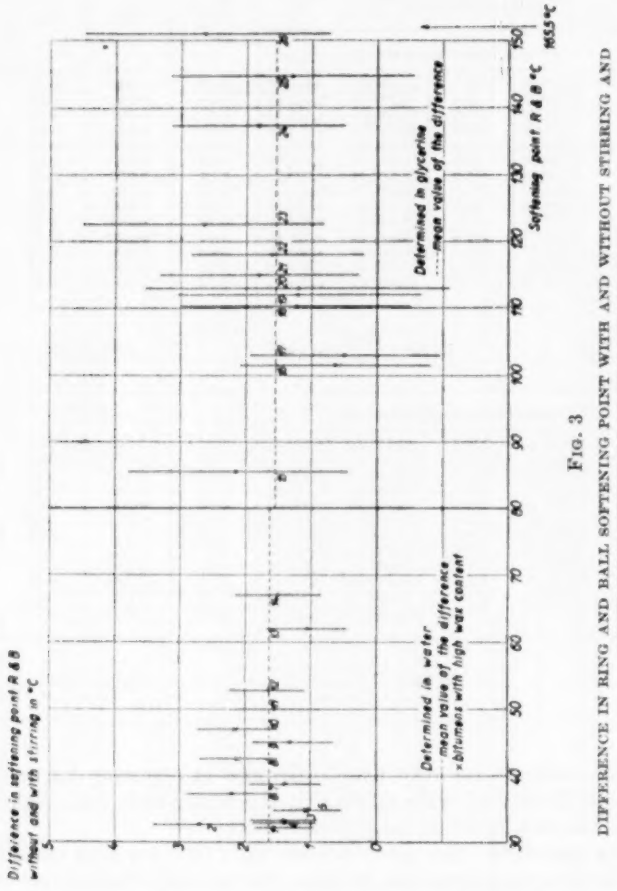
Difference in softening point R & B without and with stirring in °C
Determined in water
mean value of the difference
= bitumens with high wax content
Determined in glycerine
mean value of the difference
Softening point R & B °C
155.5°C

FIG. 3
DIFFERENCE IN RING AND BALL SOFTENING POINT WITH AND WITHOUT STIRRING AND CONFIDENCE INTERVALS OF THIS DIFFERENCE

certainly some difference in results between determinations with and without stirring.

(2) This difference is neither a function of the softening point temperature, nor of the paraffin wax content of the bitumen.

Therefore, a mean difference can be determined both for the determinations in the water-bath and for those in the glycerine-bath, as has been done in Table VI. These mean differences $(\overline{X_1 - X_2})$ are 1·65° and 1·55° C for the determinations in the water-bath and the glycerine-bath, respec-

tively. The " standard deviations of the mean " of these averages are 0·13° and 0·20° C, respectively.

TABLE V

Analysis of Variance

Bartlett's test

Group	$\Sigma n - k$	$\Sigma\left[\Sigma x^2 - \frac{(\Sigma x)^2}{n}\right]$	S_0^2	$\ln S_0^2$	$(\Sigma n - k) \ln S_0^2$
1	32	2·36	0·0738	−2·6064	−83·405
2	19	10·22	0·5379	−0·6199	−11·778
3	28	1·64	0·0586	−2·8370	−79·436
4	22	6·71	0·3050	−1·1870	−26·123
	Σ 101	20·93			−200·742

$$S^2 = \frac{20{\cdot}93}{101} = 0{\cdot}2072 \qquad B = 101 \ln 0{\cdot}2072 + 200{\cdot}742 = 41{\cdot}761$$

$$C = 1 + \tfrac{1}{3}(0{\cdot}15514) = 1{\cdot}0172$$

$$B/C = 41{\cdot}05$$

So the chance of differences in variances being not significant is less than 0·001.

F-test

Comparing groups	$F = \frac{(S_0^2)_1}{(S_0^2)_2}$	$(\Sigma n - k)_1$	$(\Sigma n - k)_2$	Level of significance
1 : 2	7·29	19	32	<0·001
3 : 4	5·20	22	28	<0·001
1 : 3	1·26	32	28	>0·20
2 : 4	1·76	19	22	>0·10 and <0·20

There is thus no real difference between these mean differences either and according to Table VI for all series together *the mean difference in the determination of the softening point without and with stirring is* 1·60 ± 0·31° C in which ±0·31° C represents the confidence interval for 99 per cent certainty.

FURTHER PRACTICAL RESULTS

As there exists no difference in accuracy between the R. and B. determinations without and with stirring, but only a difference in accuracy in the R. and B. determination carried out in the water- and the glycerine-bath, we can now, *disregarding the influence of pretreatment*, calculate the standard deviation (S_0, from the table given above) for the R. and B. determinations in the water-bath at 0·26° C and for the determination in the glycerine-bath at 0·64° C. The repeatability will then be 0·78° C in the range of 30° to 80° C and 1·92° C upwards of 80° C.

The influence of the pretreatment has not been determined exactly, but the few figures available show that the pretreatment, provided it is not carried out under extreme conditions, may cause differences of 0·5° C for determinations below 80° C and 1·5° C for determinations above 80° C. The above calculated repeatability will, therefore, certainly have to be

TABLE VI

Statistical Calculations

Difference in R. and B. temperature without and with stirring

Series no.	$\bar{X}_1$	m_1	$\bar{X}_2$	m_2	$\bar{X}_1 - \bar{X}_2$	$\sqrt{m_1^2 + m_2^2}$	$g\sqrt{m_1^2 + m_2^2}$, $g = 2{\cdot}75$	$((\bar{X}_1 - \bar{X}_2) - (\bar{\bar{X}}_1 - \bar{\bar{X}}_2))^2$
	Determinations in water-bath							
1	33·83	0·14	32·28	0·12	1·55	0·19	0·52	0·0100
2	35·40	0·19	32·70	0·17	2·70	0·26	0·72	1·1025
3	35·05	0·14	33·63	0·12	1·42	0·19	0·52	0·0529
4	34·48	0·12	33·08	0·11	1·40	0·16	0·44	0·0625
5	35·75	0·14	34·70	0·12	1·05	0·19	0·52	0·3600
6	39·50	0·19	37·30	0·17	2·20	0·26	0·72	0·3025
7	40·13	0·14	38·73	0·14	1·40	0·20	0·55	0·0625
8	44·53	0·16	42·43	0·14	2·10	0·21	0·58	0·2025
9	46·53	0·16	45·20	0·17	1·33	0·24	0·66	0·1024
10	49·17	0·16	47·03	0·14	2·14	0·21	0·58	0·2401
11	51·65	0·19	50·10	0·17	1·55	0·26	0·72	0·0100
12	54·43	0·14	52·80	0·14	1·63	0·20	0·55	0·0004
13	63·17	0·16	62·10	0·14	1·07	0·21	0·58	0·3364
14	68·60	0·16	67·10	0·17	1·50	0·24	0·66	0·0225
					$\overline{\bar{X}_1 - \bar{X}_2} = 1{\cdot}65$			$\Sigma = 3{\cdot}1672$ $m' = 0{\cdot}13$
	Determinations in glycerine-bath						$g = 2{\cdot}86$	
15	87·53	0·42	85·40	0·39	2·13	0·58	1·66	0·3364
16	102·33	0·42	101·68	0·28	0·65	0·51	1·46	0·8100
17	103·50	0·42	103·00	0·28	0·50	0·51	1·46	1·1025
18	111·40	0·52	110·17	0·32	0·23	0·61	1·75	0·1024
19	113·00	0·52	111·80	0·39	1·20	0·65	1·86	0·1225
20	114·00	0·73	112·80	0·39	1·20	0·81	2·32	0·1225
21	116·73	0·42	114·93	0·32	1·80	0·53	1·52	0·0625
22	119·80	0·37	118·25	0·28	1·55	0·46	1·32	0·0000
23	125·05	0·52	122·40	0·39	2·65	0·65	1·86	1·2100
24	139·10	0·37	137·28	0·28	1·82	0·64	1·32	0·0729
25	146·00	0·52	144·70	0·39	1·30	0·65	1·86	0·0625
26	168·10	0·52	165·50	0·39	2·60	0·65	1·86	1·1025
					$\overline{\bar{X}_1 - \bar{X}_2} = 1{\cdot}55$			$\Sigma = 5{\cdot}1852$ $m' = 0{\cdot}20$

Average $\overline{\bar{X}_1 - \bar{X}_2} = 1{\cdot}60°$ C with standard deviation of the mean of 0·11° C confidence interval for 99% certainty $gm = 0{\cdot}31°$ C.

increased by part of these values, so that the repeatability must be at least 1° C in the range of 30° to 80° C and 3° C for temperatures upwards of 80° C.

CONCLUSIONS

(1) The determination of the R. and B. softening point in the water-bath (30° to 80° C range) is more accurate than that in the glycerine-bath (above 80° C). Apart from the influence of the pretreatment, the standard deviation for the R. and B. determination is 0·26° C in the water-bath and 0·64° C in the glycerine-bath. Taking into account a normal pretreatment of the bitumen the repeatability is not better than 1° C in the 30° to 80° C range and 3° C for temperatures upwards of 80° C.

(2) The R. and B. softening point with stirring is 1·6° C lower than without stirring. This difference is not a function either of the softening-point temperature itself or of the nature of the bitumen.

(3) The determination of the R. and B. softening point with stirring is not appreciably more accurate than that without stirring. So there is

no point in introducing bath stirring in this determination, the less so as the lower softening point found with stirring would require an alteration in the specifications including R. and B. limits.

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CATALYTIC HYDRO-DESULPHURIZATION OF GAS OIL: ANALYSIS OF THE KINETICS OF THE REACTION

By H. Hoog *

Summary

With high-sulphur crudes now being produced at an increasing rate, hydro-desulphurization of oil may become an important refining tool. The kinetics of this catalytic reaction

$$C_nH_mS_p + xH_2 \longrightarrow C_nH_{m+2x-2p} + pH_2S$$

have been analysed for the case of a Middle East gas oil, treated at 375° C and elevated hydrogen pressure in the vapour phase over a catalyst active for desulphurization by hydrogenation.

By comparison with two narrow fractions, cut from the original wide-range gas oil, it was found that the reaction may conveniently be described by a first-order mechanism, but that considerable differences in reaction-velocity between the lighter and heavier sulphur compounds present in the oil prevent the calculation of an overall rate-constant.

When considering only the initial reaction velocity, it was shown that the rate constant is affected not only by the hydrogen partial pressure, but also to a considerable extent by the oil partial pressure. The addition of a supposedly inert diluent (N_2) to the hydrogenating gas was found to suppress the reaction velocity at constant hydrogen partial pressure.

These effects may be explained by assuming a preferential adsorption of oil molecules on the catalyst surface, whereas the remaining free surface is covered with hydrogen. The extent of coverage with hydrogen will depend on the hydrogen partial pressure. In case nitrogen is present, this component is adsorbed as well, and hydrogen and nitrogen then compete for the free surface. Hydrogen appears, however, to be adsorbed considerably more readily than nitrogen.

Introduction

The refining of mineral oil fractions by hydrogenation, and especially the reduction of the sulphur content by hydro-desulphurization, has long formed an object of research in the oil industry.[1, 2]

With high-sulphur crudes now being generally produced at an increasing rate [3] the hydro-desulphurization reaction, previously of direct importance only in regions of typical high-sulphur crudes (California [4, 5]), is becoming of prime interest to the oil industry in general. Research in this field has consequently gained considerable impetus.[6]

As one aspect of work of this type carried out by the Amsterdam Laboratory of the Royal Dutch/Shell Group, some studies were made of the kinetics and mechanism of the process, the results of which are presented in this paper.

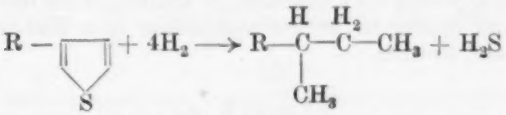
Scope of this Survey

Hydro-desulphurization of oil essentially consists of the reaction between hydrogen and the sulphur compounds present in the oil to form one or two hydrocarbon molecules and hydrogen sulphide.

* Koninklijke/Shell-Laboratorium, Amsterdam.

$$R.S.H. + H_2 \longrightarrow RH + H_2S$$

$$R(S)_nR^1 + (n+1)H_2 \longrightarrow RH + R^1H + nH_2S$$



The reaction is normally carried out at moderately elevated pressure and temperature by passing the oil vapours and an excess of hydrogen over a catalyst. Catalysts composed of metal oxides or sulphides of the elements from the sixth and eighth groups of the Periodic System, used as such or together with a carrier material, have been shown to be active for the reaction under consideration.[4]

It may be expected that the rate of the reaction will primarily be governed by the intrinsic catalyst activity, the reaction temperature, and the hydrogen pressure. When these conditions are set, the conversion would depend only on the average contact time, as determined by the combination of specific oil-space velocity (kg oil per litre of catalyst per hour, indicated as WHSV, *i.e.*, weight-hourly-space-velocity), and hydrogen gas rate, GR (in standard cubic metres of hydrogen per ton of oil fed to the reaction space).

However, when hydro-desulphurizing various gas oils over a catalyst of the cobalt molybdena carrier type active for desulphurization by hydrogenation, and when subsequently plotting the actual conversion versus apparent contact time, it was invariably found that definitely different curves are obtained for different gas rates, for a given contact time the conversion being higher at a higher gas rate.

As in the range of operating conditions employed the gas rate was always rather high, differences in hydrogen partial pressure could not explain the effects found, and it was concluded that these must be due to differences in the oil partial pressure.

The object of this study was to determine quantitatively the effect of both the oil partial pressure and the hydrogen partial pressure on the rate of reaction.

To this end measurements were carried out, desulphurizing a certain gas oil over a certain catalyst at a standard temperature. Different hydrogen-to-oil ratios were used and different total pressures; consequently, a series of measurements at constant hydrogen pressure with different oil partial pressures, and a series with constant oil pressure and different hydrogen partial pressures were obtained. The effect of the presence of an inert diluent with the hydrogen was ascertained by working with a hydrogen–nitrogen mixture. The contact time was varied over a wide range by variation of the oil space velocity. The results were analysed and correlated by computing a first-order rate-constant.

To complete the picture, this rate-constant was also measured for two narrow fractions taken from the wide-range gas oil generally used in this work.

Theoretical Considerations

With the high gas rates used in this work (6–60 mol of hydrogen per mol of oil, *i.e.*, 80–800 mol of hydrogen per mol of sulphur compound) the

hydrogen partial pressure is essentially constant all through the catalyst bed.

The simplest approach for a quantitative analysis of the reaction-kinetics, therefore, would appear to be the assumption of a first-order reaction-mechanism,* and to write :—

$$\frac{dp_S}{dt} = -k \cdot p_S \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

in which p_S = partial pressure of the sulphur-bearing compounds in the oil,
t = contact time,
k = rate constant.

As the real contact time will be proportional to the apparent contact time, τ, and as it may be desirable to indicate in the symbols that the rate constant holds numerically only for a given hydrogen partial pressure, p_H, the above equation may be written :

$$\frac{dp_S}{d\tau} = -k_{p_H} \cdot p_S \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The preliminary work had indicated that the oil partial pressure affects the velocity of the reaction. In order to account for this factor it was tentatively assumed that in principle equation (2) will remain valid but should be read :—

$$\frac{dp_S}{d\tau} = -k_{p_H p_O} \cdot p_S \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

in which $k_{p_H p_O}$ now indicates the rate constant obtaining for a given combination of catalyst, temperature, hydrogen partial pressure, and oil partial pressure.

Integration of the first-order reaction then leads to :—

$$\ln \frac{p_S}{{}_0p_S} = -k_{p_H p_O} \cdot \tau \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

in which p_S = partial pressure of sulphur compounds at the end of the catalyst bed,
${}_0p_S$ = corresponding partial pressure at inlet of catalyst bed.

Assuming—again as a first approximation—that the ratio of average molecular weight of sulphur compounds and oil does not change during the reaction (in other words that lighter or heavier sulphur compounds are not hydrogenated selectively) the ratio $\frac{p_S}{{}_0p_S}$ equals the ratio of final and initial sulphur concentration in the oil. This " fractional sulphur retention " can

* This is not the method commonly used in the kinetic study of heterogeneous catalytic reactions. However, after completing the study, Dr Schuit of the Amsterdam laboratory analysed the data by a different approach, in which he assumed that the adsorption law, obeyed by the gases in question, is the Langmuir law, while the rate of adsorption and desorption was assumed to be very large as compared with the chemical reactions occurring. His conclusions supported the above analyses.

be determined by conventional sulphur analysis in product and feed. For convenience, the per cent sulphur retention

$$\left(100 \times \frac{c_S}{{}_0c_S} = 100\,\frac{p_S}{{}_0p_S}\right)$$ was used in this work.

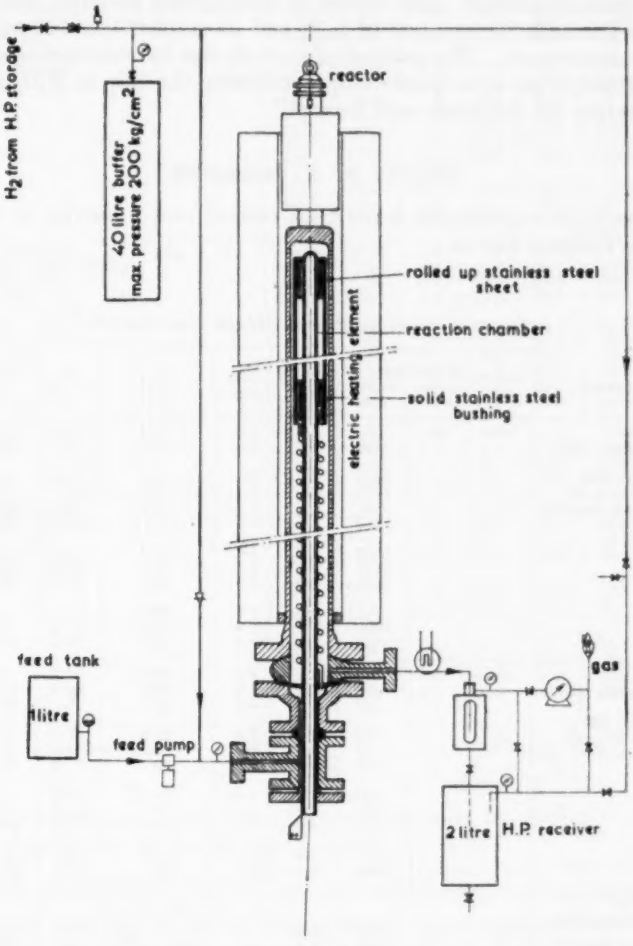


FIG. 1

SCHEMATIC DIAGRAM OF DESULPHURIZATION EQUIPMENT

EXPERIMENTAL TECHNIQUE

All experiments were carried out in small-scale high-pressure equipment, a simplified diagram of which is given in Fig. 1. The oil was pumped to the reactor by a proportioning plunger pump. The hydrogen was taken from a buffer vessel, and fed to the reactor via a pressure-control valve;

the flow rate was controlled by a needle valve in the exit line from the high-pressure separator, and the quantity was thereafter measured by a wet-gas meter. No allowance was made for the hydrogen consumed in the reaction, as this quantity amounted at most to 5 per cent of the total gas rate, and in most experiments was 2 per cent or less.

The reaction product, after release to atmospheric pressure, was washed with caustic soda for removal of H_2S, and its sulphur content was subsequently determined. The method of analysis was by combusting a sample in a current of air over quartz chips, collecting the SO_2 in H_2O_2 solution, and titrating the sulphuric acid formed.[7]

Survey of Experiments

Six series of experiments have been carried out, a survey of which is given in Tables I and II.

Table I

Survey of Experiments with Middle East Gas Oil

Feed stock	Temp. °C	Pressure atm	Gas rate SCM/ton	WHSV kg/l.h.	p_{oil}, atm	p_{H_2}, atm	ΔS, % wt	100—ΔS, % wt	τ*
M.E. gas oil Boiling range, 260°–350° C Mol. weight, 236 Sulphur, 1·25% wt Reaction gas, pure H_2	375	51	735	3·0	5·8	45·2	87·0	13·0	20·3
			740	6·0	5·8	45·2	77·7	22·3	10·1
			1480	1·0	3·1	47·9	96·0	4·0	32·2
			1488	3·0	3·1	47·9	88·8	11·2	10·7
			1465	5·9	3·1	47·9	72·7	27·3	5·5
			1470	8·2	3·1	47·9	65·6	34·4	4·0
			2860	1·0	1·6	49·4	94·5	5·5	17·2
			2810	3·0	1·6	49·4	86·5	13·5	5·7
			2990	6·0	1·6	49·4	67·2	32·8	2·75
			6100	0·5	0·8	50·2	94·4	5·6	16·4
			6000	1·0	0·8	50·2	91·3	8·7	8·4
			5950	3·0	0·8	50·2	78·5	21·5	2·8
M.E. gas oil Boiling range, 260°–350° C Mol. weight, 236 Sulphur, 1·30% wt Reaction gas, pure H_2	375	26	525	1·0	4·0	22·0	97·7	2·3	41·6
			520	2·9	4·0	22·0	85·4	14·6	14·5
			520	4·8	4·0	22·0	73·1	26·9	8·8
			780	0·9	2·8	23·2	97·7	2·3	32·8
			740	3·0	2·9	23·1	85·4	14·6	10·3
			758	4·9	2·9	23·1	77·3	22·7	6·2
			1500	1·0	1·55	24·45	96·9	3·1	16·2
			1523	2·95	1·5	24·5	81·6	18·4	5·4
			1508	4·95	1·5	24·5	70·0	30·0	3·3
			2975	1·0	0·8	25·2	93·9	6·1	8·5
			3050	2·9	0·8	25·2	75·4	24·6	2·8
M.E. gas oil Boiling range, 260°–350° C Mol. weight, 236 Sulphur, 1·30% wt Reaction gas, H_2/N_2 (45/55) by vol	375	51	3000	1·0	1·6	p_{H_2} 22·2 / p_{N_2} 27·2	86·2	13·8	16·5
			3000	3·0	1·6	22·2 / 27·2	76·2	23·8	5·5
			3000	6·0	1·6	22·2 / 27·2	53·0	47·0	2·75

* $\tau = \dfrac{P\ (\text{abs}) \times 10^4}{\text{WHSV}\ (GR + 100)}$ in which relationship, pressure, space velocity, gas rate, and molecular weight are taken into account. The reaction temperature being constant throughout the total series of our experiments, no temperature-factor was included in the τ-formula. The same applies to the porosity of the catalyst.

In all experiments a standard catalyst preparation was used, which was known from previous work to have a high desulphurization activity and a

TABLE II

Survey of Experiments with Narrow Cuts from Middle East Gas Oil

Feed stock	Temp., °C	Pressure, atm	Gas rate, SCM/ton	WHSV kg/l.h.	P_{all}, atm	P_{H_2}, atm	ΔS, % wt	100—ΔS, % wt	τ
M.E. gas-oil fraction	375	51	1545	1·0	3·0	48·0	96·0	4·0	31·0 ‡
Boiling range, 290°–300° C			1500	3·0	3·1	47·9	96·0	4·0	10·6
Mol. weight, 233 *			1635	5·5	2·8	48·2	89·2	10·8	5·3[a]
Sulphur, 1·20% wt									
Reaction gas, pure H_2			1550	4·0	3·0	48·0	90·0	10·0	7·8
			1660	7·3	2·8	48·2	73·8	26·2	4·0
			2980	1·0	1·6	49·4	95·0	5·0	16·5[a]
			3017	3·0	1·6	49·4	95·0	5·0	5·5
			3083	5·8	1·5	49·5	85·0	15·0	2·8
			3070	3·9	1·5	49·5	87·1	12·9	4·1
			3175	5·7	1·5	49·5	78·3	21·7	2·7[a]
			6045	2·0	0·8	50·2	92·5	7·5	4·2
			6210	2·9	0·8	50·2	86·7	13·3	2·8
			6130	3·9	0·8	50·2	80·0	20·0	2·1
M.E. gas-oil fraction	375	11	2605	0·50	0·4	10·6	94·2	5·8	8·1[a]
Boiling range, 290°–300° C			2545	1·02	0·4	10·6	86·7	13·3	4·1
Mol. weight, 333 *			2675	1·97	0·4	10·6	70·8	29·2	2·0
Sulphur, 1·20% wt			2585	2·99	0·4	10·6	54·2	45·8	1·4
Reaction gas, pure H_2			1112	1·47	0·9	10·1	81·7	18·3	6·2
			1120	0·91	0·9	10·1	91·7	8·3	9·9
			1157	0·51	0·8	10·2	93·8	6·2	17·2
			1155	1·02	0·8	10·2	91·7	8·3	8·6
			1127	2·06	0·9	10·1	76·7	23·3	4·3
			1235	2·01	0·8	10·2	65·0	35·0	2·8
			568	0·49	1·6	9·4	95·0	5·0	33·6
			580	0·95	1·6	9·4	91·7	8·3	17·0
			548	2·01	1·6	9·4	80·0	20·0	8·4[a]
			622	2·74	1·5	9·5	69·2	30·8	5·6
M.E. gas-oil fraction	375	51	1405	1·0	2·9	48·1	92·1	7·9	34·2 §
Boiling range, 230°–340° C			1385	2·0	2·9	48·1	82·4	17·6	17·2
Mol. weight, 268 †			1400	3·1	2·9	48·1	67·7	32·3	11·0
Sulphur, 1·76% wt			1600	5·6	2·5	48·5	56·2	43·8	5·4
Reaction gas, pure H_2			2880	1·0[a]	1·4	49·6	93·8	6·2	16·3
			2920	3·1	1·4	49·6	72·7	27·3	5·4[a]
			3080	5·8	1·3	49·7	54·6	45·4	2·8
			5930	0·7[a]	0·7	50·3	93·7	6·3	11·3
			6130	1·0	0·7	50·3	90·9	9·1	8·3
			6030	1·7	0·7	50·3	79·0	21·0	4·9
			5930	3·0	0·7	50·3	66·5	33·5	2·8

* Assumed C_{14+}.

† Assumed C_{19}.

‡ $\tau = \dfrac{P\,(\text{abs}) \times 10^3}{\text{WHSV}\,(\text{GR} + 100)}$.

§ $\tau = \dfrac{P\,(\text{abs}) \times 10^3}{\text{WHSV}\,(\text{GR} + 85)}$.

very good resistance to poisoning. In consequence, no decline of catalyst activity was noticed in any of the experimental series.

For all experiments the reaction temperature was 375° C. From previous investigations it was known that full catalyst activity is attained, and that no cracking of the oil need be feared, at this temperature.

In three series of experiments a full-range gas oil of Middle East origin was used.

M.E. gas oil	
I.B.P. ° C.	260
10 per cent	274
30 per cent	281
50 per cent	291
70 per cent	305
90 per cent	329
F.B.P.	350
vol per cent over	99
S per cent wt	1·30

The total pressure was 51 and 26 atm, respectively, in Series I and II; in Series III it was again 51 atm, but the reaction gas was a H_2/N_2 mixture containing 45 vol per cent H_2. In three further series, narrow fractions from the same M.E. gas oil were used as the feed stock, viz., the fraction 290° to 300° C and the fraction 330° to 340° C. In these experiments the total pressure was 51 atm and 11 atm respectively, and pure hydrogen was used as the reaction gas.

Discussion of Results

A. *Shape of Conversion–Contact Time Curves*

When plotting the logarithm of the per cent sulphur retention versus the apparent contact time for the full-range gas oil (Figs. 2 and 3) it became

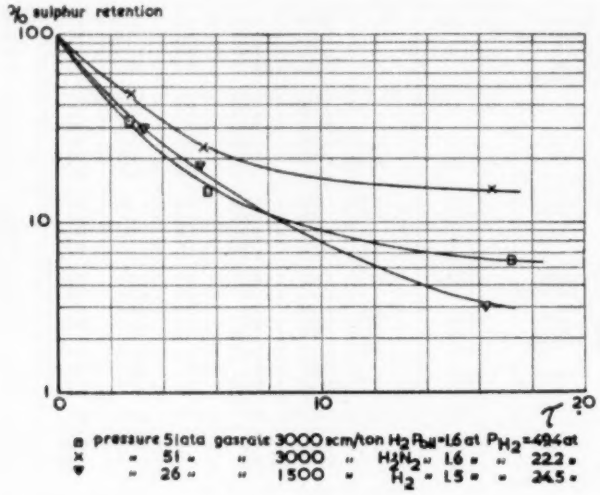

% sulphur retention
100
10
1
0
10
20
τ
● pressure 51 atm gasrate 3000 nm/ton H_2 P_{H_2}=16 at P_{H_2}=49.4 at
× " 51 " " 3000 " H_2N_2 " 16 " " 22.2 "
▼ " 26 " " 1500 " H_2 " 15 " " 24.5 "

Fig. 2

HYDRO-DESULPHURIZATION OF M.E. GAS OIL 260°–350° C; MOL. WT. 236; S, 1·3 PER CENT WT

Catalyst	CLA 5117
Temperature	375° C
Pressure	varied
Gas composition	100% H_2 or 45% H_2 55% N_2

at once evident that at constant gas rate the log retention *vs* τ plot is on straight line but is definitely curved.

Consequently, for full-range gas oil the results do not comply with the approximation :—

$$\log 100 \frac{p_S}{{}_0p_S} = - k_{p_H p_0} \cdot \tau$$

$k_{p_H p_0}$ being high at high-sulphur-retention levels and smaller at lower levels.

With the narrow gas-oil fractions, on the other hand, in the log retention

vs τ plot for a given gas rate (Figs. 4 and 5) the experimental points fall—within the experimental inaccuracy—fairly well along straight lines down to a level of about 5 per cent sulphur retention. Moreover, when comparing the slopes of the curves for the two fractions it is evident *that with the lighter fraction desulphurization proceeds considerably faster than with the heavier cut.*

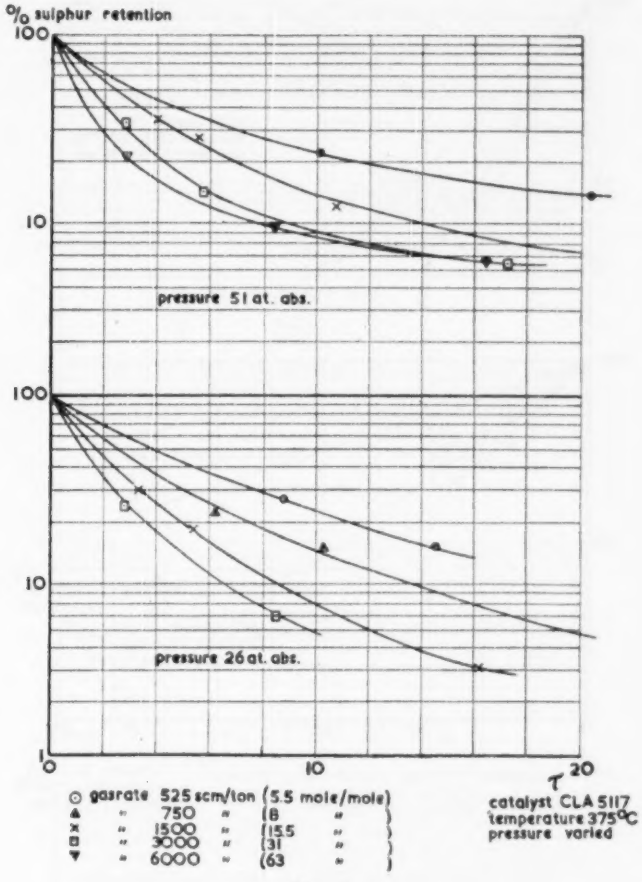


FIG. 3

HYDRO-DESULPHURIZATION OF M.E. GAS OIL, 260°–350° C; MOL. WT., 236; S, 1·25% WT.

As a result of this "light–heavy selectivity" any rate curve for wide-range oil is the resultant of an integration of rate curves for a series of narrow cuts of increasing molecular weight. The actual rate curves found for the full-range gas oil and the corresponding narrow fractions accord well with this interpretation of the results (Fig. 6).

No explanation can be given as yet for the phenomenon of light–heavy selectivity. It may be partially connected with the occurrence of different

types of sulphur compounds in the various fractions, but it is felt more likely to be a matter of steric effects : the higher the molecular weight of the sulphur compound, the more the sulphur atom may be shielded from the hydrogen atoms by hydrocarbon groups.*

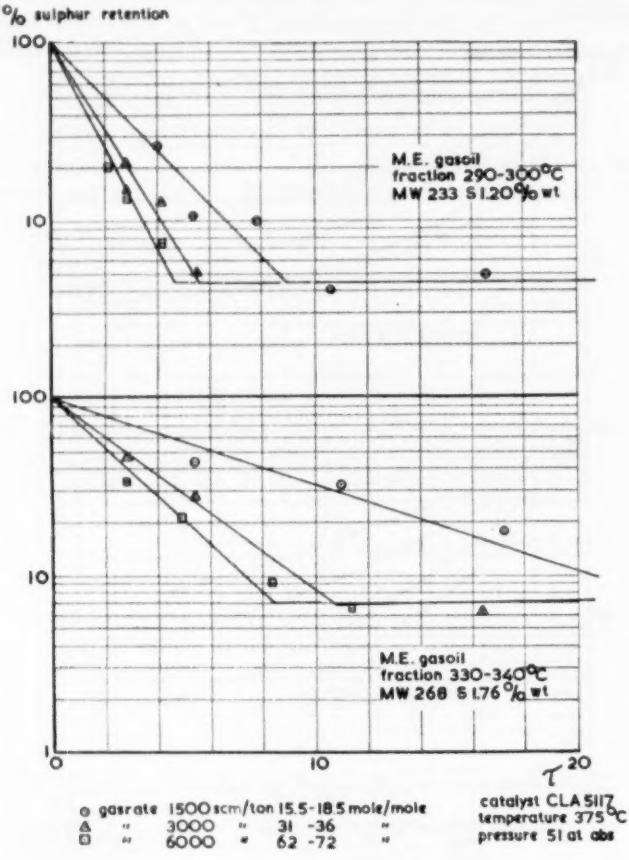


FIG. 4

HYDRO-DESULPHURIZATION OF GAS-OIL FRACTIONS

It should be noted that in all series of experiments a final sulphur retention was reached at which sulphur removal appears to stop completely. This level, located at about 5 per cent of the original sulphur content, may be the result of the presence of small amounts of highly " refractory " sulphur compounds, but no definite proof is available for this hypothesis.

* An alternative explanation was arrived at by Dr Schuit in his analysis, indicating that this phenomenon may be due to an increase in specific adsorbability with increasing molecular weight, the inherent reactivity of the sulphur-bearing molecules being probably independent of the molecular weight.

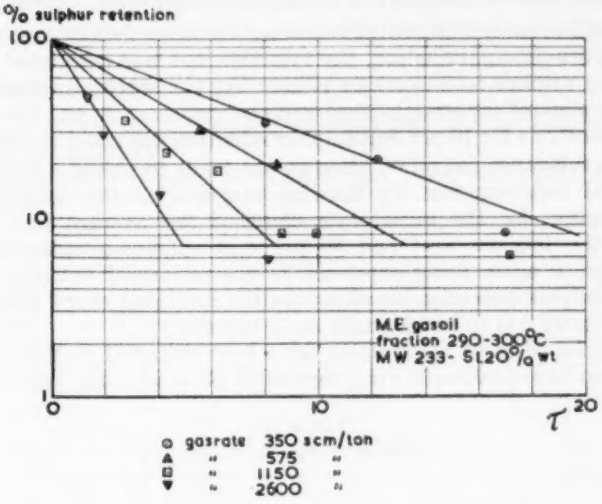


FIG. 5

HYDRO-DESULPHURIZATION OF GAS-OIL FRACTIONS

Catalyst	CLA 5117
Temperature	375° C
Pressure	11 atm. abs.

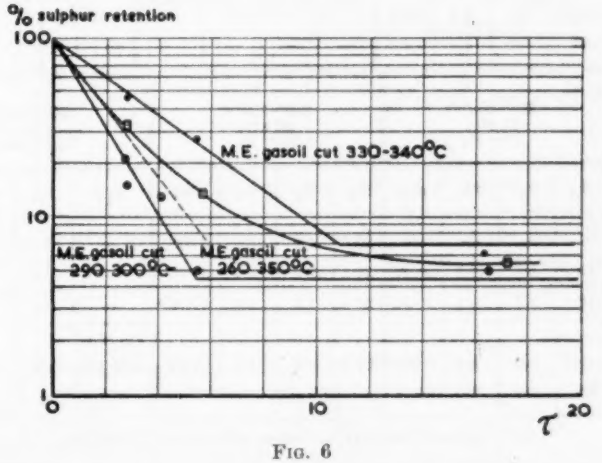


FIG. 6

HYDRO-DESULPHURIZATION OF GAS OIL

Catalyst	CLA 5117
Temperature	375° C
Pressure	51 atm. abs.
Gas rate	3000 SCM/ton

B. *Semi-quantitative Analysis of the Effect of Oil Partial Pressure*

In order to obtain a quantitative indication of the factors controlling the rate of hydro-desulphurization, the rate constant was calculated from the various log sulphur-retention *vs* τ plots. For the narrow fractions (Figs. 4 and 5) the slope of the straight lines could be used as such, and for simplicity the reciprocal of τ for 10 per cent sulphur retention was taken to equal $k_{p_H \cdot p_O}$.

For the full-range gas oil no attempt was made to obtain a figure for the real initial rate constant by drawing tangents to the curves. As an approximation for the initial rate constant the average rate constant between the 100 per cent and 50 per cent sulphur-retention level was determined, k again being expressed as the reciprocal value of τ for 10 per cent sulphur retention measured on the indicated chord (*vide* Fig. 6). For these cases k is to be indicated as ${}_i k$, initial k.

The results of these calculations have been collected in Table III, and the various rate-constants were correlated on a semi-log plot *vs* the oil

TABLE III

Survey of Rate Constants

Gas oil feed stock : Pressure : Gas :	290°–300° C 51 atm pure H_2				290°–300° C 11 atm pure H_2				330°–340° C 51 atm pure H_2			
Gas rate (approx.)	p_H	p_O	τ_{10}	k_{10}	p_H	p_O	τ_{10}	k_{10}	p_H	p_O	τ_{10}	k_{10}
525	—	—	—	—	8·75	2·35	18·0	0·056	—	—	—	—
					—	—	—	—				
750	—	—	—	—	9·5	1·6	11·4	0·088	—	—	—	—
					—	—	—	—				
1500	48	3·0	6·6	0·151	10	0·85	7·3	0·137	48	2·9	20·3	0·049
					—	—	—	—				
3000	49·5	1·5	4·2	0·239	10·5	0·4	4·3	0·233	49·5	1·4	9·2	0·109
					—	—	—	—				
6000	50	0·8	3·4	0·295	—	—	—	—	50	0·7	7·2	0·139

Gas oil feed stock : Pressure : Gas :	260°–350° C 51 atm pure H_2				260°–350° C 26 atm pure H_2				260°–350° C 51 atm H_2/N_2 (45/55)			
Gas rate (approx.)	p_H	p_O	τ_{10}	${}_i k_{10}$	p_H	p_O	τ_{10}	${}_i k_{10}$	p_H	p_O	τ_{10}	${}_i k_{10}$
525	—	—	—	—	22	4·0	13·2	0·076	—	—	—	—
750	45	5·8	10·6	0·095	23	2·9	8·7	0·115	—	—	—	—
1500	48	3·1	8·0	0·125	24·5	1·5	5·1	0·175 *	—	—	—	—
									p_{H_2} | p_{N_2}			
3000	49·5	1·6	4·8	0·208	25	0·8	4·1	0·244	22·2 | 27·2	1·6	7·8	0·128 *
6000	50	0·8	2·9	0·345	—	—	—	—	—	—	—	—

* To be compared for equal hydrogen- and oil-partial pressures.

partial pressure (Fig. 7). In view of the fact that all available data indicate a straight-line correlation, the relationship between rate-constant and oil partial pressure may be expressed by a function

$$k_{p_H p_O} = k_{p_H,\, p_O = 0} \cdot 10^{-\text{const.} \cdot p_O}.$$

This suggests some type of preferential adsorption of oil molecules on the surface, which thereafter is not available any more for the hydrogenation reaction.

From the slope of the k *vs* p_o lines it may be derived that :—

(1) the effect of oil partial pressure is greater according as the feed stocks are heavier;

(2) the effect is more pronounced the lower the hydrogen partial pressure.

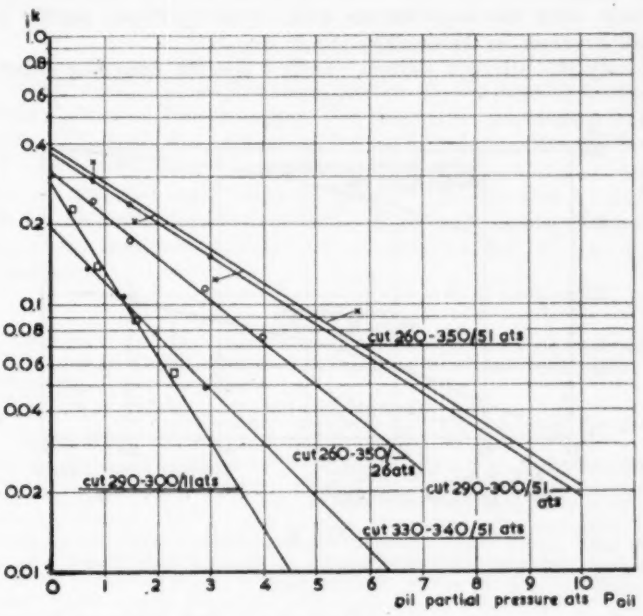


FIG. 7

HYDRO-DESULPHURIZATION OF GAS-OIL FRACTIONS—CORRELATION OF REACTION-RATE CONSTANT WITH OIL PARTIAL PRESSURE

This may be still more clearly illustrated by comparing the rate constant at infinite hydrogen dilution and at a fixed, arbitrarily chosen, oil pressure of 2·5 atm, which two values were derived from the correlation plot :—

M.E. gas oil, ° C	p_H atm	$_ik$ at $p_O = 0$	$_ik$ at $p_O = 2{\cdot}5$ atm
Narrow Cut 290–300 . . .	48–51	0·38	0·18
Narrow Cut 290–300 . . .	9·5–11	0·29	0·04
Narrow Cut 330–340 . . .	48–51	0·19	0·06
Range 260–350	48–51	0·40	0·19
Range 260–350	22–26	0·32	0·13

From these figures it is evident that, whereas the effect of hydrogen partial pressure at infinite hydrogen dilution (zero oil partial pressure) is

rather limited, this does not hold at a finite oil partial pressure where reaction rate rapidly falls off when decreasing the hydrogen pressure from about 50 atm to lower values. For a graphical presentation *vide* Fig. 8.

Of special interest from a general catalytic point of view are the results obtained when a mixture of hydrogen and nitrogen was used instead of pure hydrogen.

The rate curve for the relative experiments (Fig. 2) indicates that at equal oil partial pressure desulphurization proceeds much more slowly, not only in comparison with the case for equal total pressure, but also in comparison with the experiments with equal hydrogen partial pressure (compare k-values in Table III).

Obviously the nitrogen diluent exerts a specific retarding effect in the reaction.

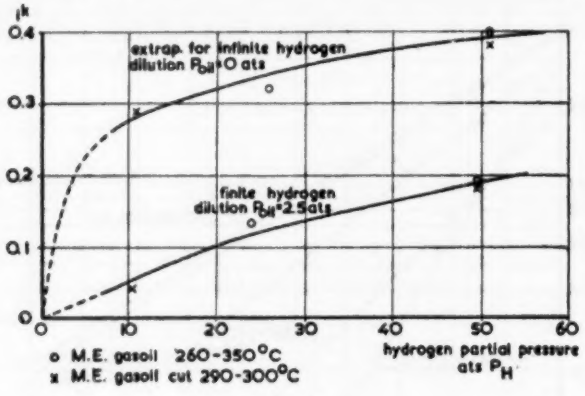


FIG. 8

HYDRO-DESULPHURIZATION OF GAS-OIL FRACTIONS

C. *Hypothesis Explaining the Effects of Oil and Hydrogen Pressure and Diluent*

To explain the results obtained the following hypothesis is thought to cover all aspects :

The reaction proceeds on the surface of the catalyst by interaction of the sulphur-bearing molecules and hydrogen atoms formed through activated adsorption of hydrogen molecules. Oil molecules are more strongly adsorbed than hydrogen molecules, and therefore may preferentially cover part of the surface, leaving less surface available for dissociation of hydrogen molecules. This would explain the decrease in rate constant with increasing oil partial pressure.

Results seem to indicate that an adsorbed oil molecule is more easily expelled from the surface at higher hydrogen pressures, or, what amounts to the same thing, less easily adsorbed on an empty site, resulting in a smaller effect of increasing oil pressure at a higher hydrogen pressure. This is not surprising : in a layer of oil molecules the van der Waals' attraction between the oil molecules will tend to lower the energy of the layer. This attraction is, however, much smaller in a mixed oil–hydrogen layer.

If, on the other hand, nitrogen molecules are present besides hydrogen, they can also compete for free sites on the surface, and accordingly may cause a reduction in the concentration of hydrogen on the surface, thus giving the lower rate constant when working with H_2–N_2 mixture.

From the magnitude of the rate constants found under about equal conditions of temperature, oil partial pressure, and hydrogen partial pressure, with pure hydrogen and hydrogen–nitrogen mixture, respectively, it might be concluded that under the conditions applied about 75 per cent of the free surface is covered with hydrogen, a ratio which would not seem improbable.

Acknowledgments

The author wishes to express his thanks to the management of the Bataafsche Petroleum Maatschappij, The Hague, for permission to publish this paper. The work was carried out by the Development and Pilot Plant Staff of the Amsterdam Royal Dutch/Shell Laboratory under daily thorough and devoted supervision of Messrs J. Koome and K. A. Weeda, to whom the author is greatly indebted. Many stimulating discussions on the subject have been held with Dr G. C. A. Schuit and Ir. P. Van 't Spijker of this company.

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INSTITUTE OF PETROLEUM HYDROCARBON RESEARCH GROUP

Annual Report October 1949–September 1950

The work sponsored by the Hydrocarbon Research Group continued to be active in the already well-established fields of synthesis and spectroscopy, and the newly developed organization to deal with the technique and applications of mass spectrometry to petroleum problems made a vigorous start. The sponsoring bodies who have supported the work of the Group in the past all continued their support, with the additional membership of Manchester Oil Refinery Ltd, Petrochemicals Ltd, and Monsanto Chemicals Ltd. In consequence, the financial position of the Group remained strong, and it has been possible to continue the support of existing university groups at the same or in some cases higher levels than before and to undertake some new ventures. A number of discussions were held during the year with other firms and bodies who are interested in the work of the Group and are giving consideration to joining it. There has been every indication that the usefulness of the work done by the Group is being maintained and increased and that this form of independent co-operative research has many advantages and attractions at the present time.

Very close attention has been given to possible lines of development of techniques outside the Group's established fields. Great Britain is still lacking in properly equipped laboratories and schools of workers in several branches of physical chemistry particularly applicable to hydrocarbons. To mention one outstanding case, the amount of thermochemical and experimental thermodynamical research which is done in Britain cannot be compared with that which is being done in the U.S., and much of the latter has been organized and supported by the American Petroleum Institute. Consideration is being given to the possibility of encouraging similar work in Britain.

The Advisory Committee on Fundamental Research of the American Petroleum Institute has, through the President of the Institute of Petroleum, offered to forward for distribution to members of the Group the quarterly research reports of the five fundamental research projects which are supported by the Advisory Committee. This offer has been gratefully accepted, and arrangements are being made to reciprocate by sending copies of the Group's reports to the API. Contact is also being made with the API on possible co-operation in the preparation and availability of standard hydrocarbon samples.

Hydrocarbon Synthesis Panel

Panel Chairman : Dr F. A. Fidler
Panel Secretary : Mr H. C. Rampton

Sponsored work continued at :

Bedford College, London (Prof. E. E. Turner, F.R.S.)
Queen Mary College, London (Dr W. J. Hickinbottom)
Birmingham University (Dr C. R. Porter)

In addition a new commitment was undertaken in the support of work at the Dyson Perrins Laboratory, Oxford, under Dr J. C. Smith. The synthesis of specific hydrocarbons has ceased to be part of the programme of the Synthesis Panel—the efforts of the university groups are now devoted to more general studies of the reactions and properties of hydrocarbons, and the synthesis interest is now in generalized routes to classes of hydrocarbons rather than in specific compounds.

The work of the Bedford College group has been mainly concerned with the reaction of sodium aryls and alkyls and their uses in the synthesis of alkyl benzenes. It was found that by refluxing sodium phenyl with toluene, complete conversion occurred to give sodium benzyl, and this has been used for a wide variety of substituted benzenes, including phenyl*cyclo*hexylmethane : the yields and techniques developed in this work show considerable improvements over work previously recorded in the literature. The programme has been extended recently to lithium and potassium aryls, both of which are readily prepared. This work on the interaction of various metal aryls and alkyls with aromatics is continuing and should provide simple routes to many alkyl benzenes which are not readily available.

At Queen Mary College work has continued along two lines. A study is being made of the oxidation of olefins by chromic acid in acetic anhydride, with particular reference to the course of the reaction and the formation of epoxides and other intermediate products. Another line of investigation is proceeding on the problem of introducing a quaternary carbon atom into a preformed carbon chain; two methods which are being used for this are the re-arrangement of 1 : 2-glycols and the preparation of suitable alkyl halides from highly substituted *cyclo*hexanones.

At Birmingham University work is proceeding on the addition of nitrogen tetroxide to olefins with the object of developing methods for identifying the position of the double bond; work is also being done on the addition of nitrogen trioxide. Methods of synthesizing olefins with tertiary alkyl groups substituted at the double bond are also in hand, and exploratory work is being done towards the synthesis of tetra-tertiary-butyl ethylene.

The work carried out at the Dyson Perrins Laboratory, Oxford, has been a continuation of that already reported in the Institute of Petroleum *Journal* on the synthesis of alkyl naphthalenes. Further compounds with long normal side chains have been made, and the changes in physical properties with increasing length of side chain are being investigated.

Spectroscopic Panel

Panel Chairman : Mr F. Gill
Panel Secretary : Dr H. Powell

In addition to continued sponsorship of the spectroscopic research teams at Oxford and Cambridge, support has been extended during the year to Dr W. C. Price of King's College, London.

In the field of high-speed detectors, the Cambridge workers have demonstrated photo-conductivity in arsenic and tellurium and also in arsenides and antimonides, but none of these materials offers any advantage over

lead sulphide or telluride in performance. The cathode-ray spectrometer is now working successfully as a double-beam instrument with a scanning speed of $\frac{1}{12}$ second, covering a spectral range of about 2 microns. This instrument was developed by Dr Daly, and further work on it has now been undertaken by an instrument firm. At King's College special attention has been devoted to such instrumental factors as noise in amplifiers and thermocouple transformers.

Work at Oxford with polarized infra-red radiation has enabled comparison to be made between infra-red and X-ray methods for the determination of crystal structures, and it seems likely that the infra-red method will become of increasing importance. At both Oxford and Cambridge work has continued on change of spectra with change of state and on infra-red absorption at low temperatures. A particular study has been made at Cambridge of the low-temperature spectra of paraffins and attention is being given to rotational isomerism. Work is proceeding at both Oxford and Cambridge with instruments of high resolving power and especially of intensity in relation to the broadening effect of pressure on the absorption of gases in the infra-red.

Interest is also being maintained in the ultra-violet field, and a photoelectric vacuum spectrometer is being constructed at King's College which will cover the range 1400 to 3000 Å. Work is also in hand in the Raman field.

Mass Spectrometry Panel

Panel Chairman : Mr J. Blears
Panel Secretary : Mr W. J. Brown

The formation of the Mass Spectrometry Panel was reported last year, and in its first full year of operation it has shown vigour and has achieved some very useful results.

A very successful symposium was organized and held in April 1950 in Manchester by kind invitation of Metropolitan-Vickers Ltd. This meeting lasted for two full days and covered the whole range of mass spectrometry from the theory of the cracking process to applications of mass spectrometers to hydrocarbon analysis. It was attended by practically all the workers in this field in the United Kingdom, together with a number of visitors from France and Holland.

The meetings of the Mass Spectrometry Panel have proved to be very useful in bringing together those actively interested in the subject in the oil industry as well as providing regular contacts with the instrument manufacturers and university workers. A programme of co-operative analyses of synthetic hydrocarbon mixtures has been arranged with the participation of the Shell laboratories in Amsterdam. There is no doubt that this Panel is materially assisting the development and application of the mass spectrometer to the petroleum industry. It is also recognized as desirable to encourage academic research work on the technique, and arrangements are now being made to sponsor several teams of university workers who are working on various fundamental aspects of the subject.

B. W. Bradford,
Chairman, Hydrocarbon Research Group.

OBITUARIES

ARTHUR W. EASTLAKE

By the death of Arthur W. Eastlake on November 21, 1950, in his 86th year, the Institute of Petroleum loses not only another of its Founder Members, but also its co-founder, for it was the original proposal of Sir Boverton Redwood and Mr Eastlake that a professional body should be formed for the petroleum industry in Great Britain which eventually led to the formation of the Institute. Although the Institution of Petroleum Technologists, as the Institute was first called, did not come into being until 1913, for many years previously these two had been active in bringing their ideas to the notice of their colleagues and gaining support for such a body.

As early as 1904, Mr Eastlake was preparing a list of " Gentlemen eligible as Members, Associate Members, or Associates who have promised to join the Institution." This list is noteworthy in that it included such names as H. Barringer, D. M. Chambers, Col. English, L. M. Fraser, J. D. Henry, T. C. Palmer, Dr Boverton Redwood, W. Sutton, and P. C. Tennant, many of whom later figured prominently in the affairs and control of the Institution when it was formed. It is also of interest to record that at that time it was proposed that the name of the body should be " The Institution of Petroleum Engineers." This is not surprising, as Mr Eastlake's interests in those days were principally in the production and engineering branches of the industry. However, as time went on and interest in the proposal broadened, the scope of the proposed membership was widened to include all technologists engaged in the petroleum industry in any of its varied phases.

He was Honorary Secretary of the Institution and the Institute from 1915 to 1948, and from the time of its formation until the end of 1919 provided office and other accommodation for the conduct of its affairs. He served on the Council from 1914 to 1921 and 1934 to 1936, on various committees, and was a vice-president from 1921 to 1934.

Arthur W. Eastlake was a pioneer in the petroleum industry, which he first entered in 1885 or 1886. At that time he was engaged in the sinking of a pit for oil shale at Portesham, in Dorsetshire, when he came to the notice of Sir George Elliot who engaged him to go to the Ropienka oilfield, Galicia, for six months. Following this period he was engaged by Messrs Elliot and Parkinson as manager of their oilfields in Ropienka and Ustanowa, a position which he occupied for four years. Following this he spent some years on visits of inspection on behalf of Sir George Elliot to various oilfields and refineries in Galicia and other parts of Austria-Hungary. He was also responsible for the re-building of the refinery at Drohobycz during this period.

At about the turn of the century Mr Eastlake made the acquaintance of Dr (later Sir) Boverton Redwood, and on his behalf visited and reported on many prospective and producing oilfields in Europe and other parts of

the world. In 1910 the well-known partnership of Redwood and Eastlake was formed and remained in being until the death of Sir Boverton in 1919. Thereafter, the business of consulting petroleum technologists was continued, with his brother-in-law William Sutton as his partner, until their retirement in 1930.

During his active association with the consulting side of the industry, Mr Eastlake visited every country in Europe (except Portugal and Greece), made over 60 trips across the Atlantic, and also went to Mexico and Newfoundland. Among his visits to Europe were many to Russia and he was responsible for the location of the first producing well on more than one oilfield.

His literary attainments were not extensive as, like many engaged in consulting work, much of his knowledge could not be publicly disclosed. In June 1892, he read a paper on " Observations on Petroleum in Eastern Europe, and the method of drilling for it " before the Federated Institution of Mining Engineers. He was also co-author with Sir Boverton Redwood of the " Petroleum Technologists Pocket-Book " in 1915 and prepared the revised second edition in 1923.

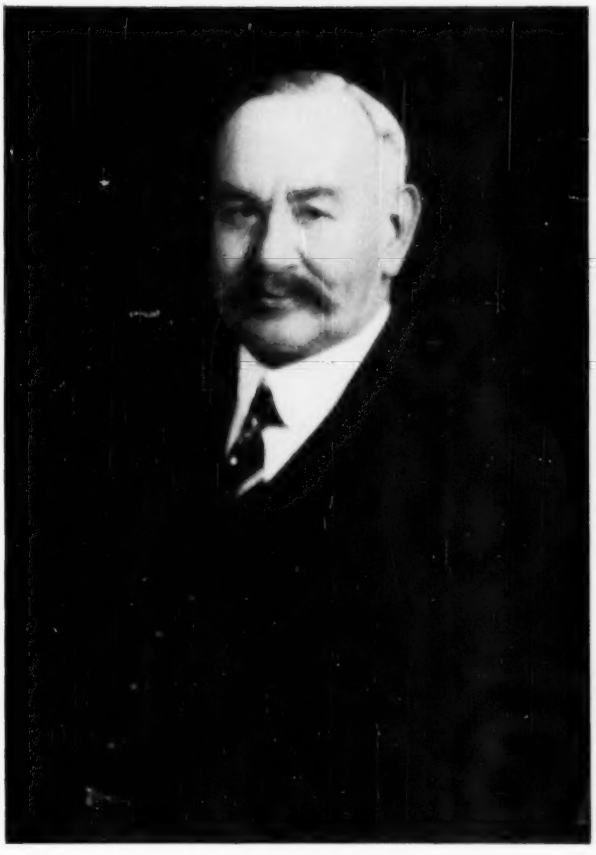
At one time Mr Eastlake had some connexion with the explosives industry and was proud to have been the first to take to the United States samples of a safety explosive, ammonite. This he demonstrated at the naval base at Sandy Hook and in various coal mines. He also worked on the erection of an explosives factory at Stanford-le-Hope, Essex, and later carried out some experimental work there.

Mr Eastlake was a Freeman of the City of London and a Liveryman of the Goldsmiths' Company. He was an early motorist, a Founder Member of the Royal Automobile Club and on that organization's Senior Hundred Roll.

He is survived by his one son, A. Lloyd Eastlake, who is a research engineer in the Sinclair Refining Company, Chicago.

Arthur W. Eastlake was of a kind and considerate disposition and had a personality which inspired confidence among his colleagues and loyalty from his employees. Those who had the good fortune to know him have lost a true friend. G. S.

Some forty-six years ago it was my joy and privilege to become " confidential secretary " to the late Sir Boverton Redwood—a very young and inexperienced secretary; Mr Arthur W. Eastlake was the first of the technical staff to be introduced to me. From that time until the " passing on " of Sir Boverton in 1919 my tasks were often very exacting and often complicated, but I was constantly helped by the knowledge, kindness, and above all sound judgment of Mr Eastlake. He was Sir Boverton's " tower of strength " in numerous difficult decisions. I wonder how many of the members of the Institute of Petroleum and others realize that a few words from Sir Boverton (after much thought) to Mr Eastlake brought into existence the Institution of Petroleum Technologists. The smile, courtesy, and sincerity of Mr Eastlake and Sir Boverton—two great " oil scientists " linked as " one "—will ever be in the thoughts of many. E. E. E.



ARTHUR W. EASTLAKE
1865–1950

[*To face p. 756.*

FREDERICK WILLOUGHBY PENNY

FREDERICK WILLOUGHBY PENNY

FREDERICK WILLOUGHBY PENNY, B.Sc., F.G.S., died in San Fernando, Trinidad, on October 28, 1950, at the age of sixty-three. He was born in Uxbridge, Middlesex, was educated at Malvern College, and concluded his studies at the University of London.

The young graduate then went to South Africa as geologist to the Witwatersrand gold-mines, but returned two years later for a course in geology at the University, Munich. In 1914 he went to Roumania, and at this time he also joined the Institution of Petroleum Technologists as an Associate Member, thus being one of the original members. However, his work in Roumania was soon abruptly ended by the first world war. After having destroyed all documents, he escaped in a cattle-truck to Russia, and via Norway and Sweden reached England possessing only the clothes which he wore. Being an oil geologist, he was exempt from military service and went to Trinidad, where he went to work in the Barrackpore field of the Trinidad Oil and Transport Company Ltd. This company was subsequently acquired by Trinidad Leaseholds Ltd., and shortly afterwards we find Penny as the sole geologist of the company. In 1919 he married, and out of a happy family life grew two sons, one of whom, Lewis, survives his father and is now senior lecturer in geology at Hull University College.

In 1920 V. C. Illing returned to Trinidad and introduced improved geologic exploration methods. Penny was immediately interested in the application of the study of foraminifera to stratigraphic correlation, and this at a time when oil-company executives still looked askance on anything considered to be of merely academic interest. He soon recognized that specific foraminiferal assemblages were to be typical for certain formations and, thus, contributed to more accurate correlation of contemporaneous Tertiary sediments. With his enthusiasm he imbued the equally ardent naturalist, Percy W. Jarvis, then manager of Barclays Bank, San Fernando, who took up and carried forward the study of foraminifera. The two became great friends, and when Penny left Trinidad in 1922 it was Jarvis who prepared those collections that finally induced J. A. Cushman to publish the fundamentally important investigations on the foraminifera of Trinidad which subsequently turned out to be of the greatest value, not only to the paleontologists working in the oil provinces of the Caribbean region, but also for world-wide correlation of Tertiary marine sediments.

From 1922 to 1924 Penny was employed with Cory Bros., during which time he made occasional visits to Trinidad and the U.S.A. However, he returned again to Roumania and remained there for thirteen years, for the greater part of the time as chief geologist to the Unirea S.A. Romana de Petrol (Phoenix Oil and Transport Company Ltd.). In 1937 he went to Uganda on exploration drilling on the shore of Lake Albert, but the second world war stopped these activities, and in 1941 he returned to Trinidad as manager and geologist for Cory Bros. The interests of this company were later on acquired by National Mining Corporation Ltd., and he stayed with this company in the capacity of adviser until his health started to fail a few years ago.

As a Fellow of the Institute he was an active participant in its affairs and served on the Committees of the Roumanian and Trinidad branches. He was greatly esteemed for the liberal way in which he helped younger colleagues and new-comers to become acquainted with local geology. His interest in geological problems remained with him to the end.

Fred Penny was one of the pioneer oil geologists in Trinidad, and his loss is keenly felt by his colleagues and friends in Trinidad.

H. G. KUGLER

FREDERICK PEEL

IT is with deep regret that we record that Frederick Peel, director and chief engineer of Messrs W. J. Fraser & Co. Ltd., died suddenly at his home at Upminster on Wednesday, December 6, 1950, in his sixty-fourth year. He was born on January 21, 1887, and received his technical education at The Marine School, South Shields, and at Sunderland Technical College.

He served an apprenticeship of six years in the shipbuilding and engineering shops of John Readhead & Sons, South Shields, and then served three years in the Mercantile Marine, rising to chief engineer. He was Premier Silver Medallist in Mechanical Engineering, City and Guilds Institute, Premier Prizeman of Goldsmiths Institute, and National Prizeman in Machine Design, Board of Education. He obtained the Extra First Class Engineers Certificate under the Board of Trade.

For three years he was with Messrs John I. Thornycroft & Co. Ltd. and Messrs Job Bros., Liverpool, engaged on the design, construction, testing, and installation of large two-cycle marine diesel engines at a time when this was work of a very pioneering nature.

In 1913 he began to work with Messrs W. J. Fraser & Co. Ltd. at Dagenham on the design and construction of a revolutionary type of two-cycle diesel engine, the main features of which have become standard practice in marine engines of this class. Work on this was suspended because of war conditions in 1915, when Mr Peel became chief draughtsman and subsequently chief engineer of Frasers.

He took up the study of chemical engineering and the design of chemical equipment in a very energetic manner, and was associated with many advances in acid, fertilizer, mineral oil, and many other types of chemical plant. He was appointed a director of the Company in 1938.

During the last few years, Mr Peel devoted a large proportion of his spare time to work on the preparation of the Standard Code of Practice for the Design and Construction of Pressure Vessels for the British Standards Institution, this work culminating in the issue of B.S. 1500 and its accompanying Material Specifications. He was a Member of the Main Committee on Pressure Vessels and of all its panels, and he personally drafted many sections of the Code.

Mr Peel became a Member of the Institute of Petroleum in 1923, was one of the earliest Members of the Institution of Chemical Engineers, and a Member of the Institute of Marine Engineers.

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Oilfield Exploration and Exploitation

Geology

2564. Apparatus for rapid mechanical analysis of sediments. K. H. Sindowski. *Erdöl u. Kohle*, 1950, **3** (7), 314–15.—The apparatus is designed to give a rapid size analysis in the range 2–0·11 mm in one operation, and by the addition of pipette gear the range can be extended down to 0·002 mm. After careful preparation to remove material coarser than 2 mm and to ensure the breakdown of loose aggregates and proper dispersal of clays, the sample is introduced into a special tube so designed that the free fall of the sediment is controlled by currents set up by turbulence. Exactly 1 cc of each of three sets of coloured grains were added to the sample before sedimentation, the sizes and colours of these being 0·02–0·035 mm, black; 0·063–0·11 mm, red; 0·2–0·35 mm, black. When sedimentation is complete these coloured grains cause the sediment to be banded, and it is then possible to make a direct estimate of seven fractions.

The method and apparatus have been patented. S. E. C.

2565. The weathering of heavy minerals and the mineralogy of sediments. R. Weyl. *Erdöl u. Kohle*, 1950, **3** (5), 209–11.—Examination of the heavy mineral content of Tertiary and Mesozoic sediments in the west Baltic region has shown that there are such extraordinary variations in deposits closely related in time and space that gross errors in interpretation would arise if the effect of weathering on the minerals were not taken into account. The relative stability of various minerals is discussed, and some examples are given of the effect of weathering on the heavy mineral content of sediments. S. E. C.

2566. Ultra-sonic preparation of rock samples. W. Wetzel. *Erdöl u. Kohle*, 1950, **3** (5), 212–14.—A brief description is given of an apparatus for the disintegration of rock samples by ultra-sonic waves. The equipment was designed primarily for freeing micro-fossils from the tougher rocks, and examples given show that it is successful for this purpose. S. E. C.

2567. The range chart as an aid in foraminiferal correlation. J. G. Bursch. *J. Palaeont*, July 1950, **24** (4), 479.—Criteria are given for the recognition of horizons where there is a marked change of fauna. Significance of these criteria in stratigraphy is discussed.

Particular associations of criteria may provide reliable markers where a single criteria is unreliable. The value of a range chart depends largely on the type of arrangement chosen, which in turn depends on the nature of the sedimentary sequence being studied, the objectives of the tabulation, the method of collecting, and the time available for study. Various arrangements are suggested.

A table showing a classification of range charts is included. C. A. F.

2568. Arizona gas well drilling ahead. Anon. *Petrol. Engr*, Aug. 1950, **22** (9), B-78.—1 Hortenstein, in Apache Country, Arizona, had an estimated gas flow of 20–40 M.c.f/day. The gas was chiefly nitrogen with only a trace of hydrocarbons. C. A. F.

2569. Geology and oil prospects of western San Jose Hills, Los Angeles County, California. F. H. Olmsted. *Calif. J. Mines & Geol.*, **46** (2), 5.—The exposed rocks of the western San Jose hills are folded Miocene and Pliocene beds which are marginal facies of the Los Angeles basin sediments. Miocene beds overlie Middle Miocene volcanics, which in turn overlie either pre-Upper Cretaceous plutonic or metamorphic rocks or pre-Middle Miocene porphyrs. The Pliocene has been divided into the Upper Pliocene Pico and the Lower Pliocene Repetto.

The structure of the area consists essentially of two anticlines with an intervening syncline. Axes trend eastwards. About eighteen wildcats have tested these structures. Production has been found in two wells in the western part of the southern anticline, where accumulation appears to be partly controlled by a fault which strikes at right angles to the anticlinal axis.

Best prospects for production are probably on the southern anticline west of the fault.

The stratigraphy and structure of the area is described in detail. An index map and outcrop photographs are included.

Eighteen references are given. C. A. F.

2570. Two new wells are added to Ventura Avenua field. Anon. *Petrol. Engr*, Aug. 1950, **22** (9), B-72.—S-1, in the Ventura Avenue field, California, initially flowed over 500 b.d. of 32° oil from a total depth of 13,450 ft.

Aloyd 160, also in the Ventura field, flowed 381 b.d. of 30·9° oil and 1,189,000 cu. ft. gas/day. C. A. F.

2571. Brings in good producer in Los Angeles basin. Anon. *Petrol. Engr*, Aug. 1950, **22** (9), B-72.—U.P. Unit 9, in the East Los Angeles field, California, produced 1047 b.d. of 34·8° oil from a total depth of 7978 ft. The field has produced approx 1,536,000 brl since it was opened in 1946. C. A. F.

2572. Preliminary report on Kirby Hill gas field. R. G. Frame. *Summary Operations Calif. Oilfields*, **35** (1), 13.—The Kirby Hill gas field, Solano County, was discovered in 1944 by Lambie 1, which blew gas at 15,000 M.c.f/day from the Middle Eocene Domengine sand from 2063 to 2368 ft.

Subsequent drilling has shown the productive limits of the field to be very irregular. Of seventeen wells drilled within the limits, only nine found production. Exploration and development of the field were completed by the end of 1948. Proved acreage is estimated at 730 acres.

The structure of the field appears to be a long, narrow, northwest–southeast-trending anticline, much faulted. Most of the wells are probably in separate fault blocks. In the eastern part of the field there is a major thrust striking northwesterly and dis-

placing about 2000 ft of beds upwards on the east. There are two separated structural highs, probably separated by a cross fault.

Due to unconformities and faulting, field correlations are difficult. Gas is produced from seven separate zones in the Eocene and Cretaceous.

Total recoverable reserves of the field at January 1949 were estimated at 33,233,151 M.c.f.

The stratigraphy and structure of the field are described in detail, and a typical electric log of the stratigraphical section is included. C. A. F.

2573. Oil and gas accumulation controlled by sedimentary facies in Eocene Wilcox to Cockfield formation, Louisiana Gulf Coast. M. Bornhauser. *Bull. Amer. Ass. Petrol. Geol.*, **34** (9), 1887–96.—The Louisiana Gulf Coast belongs to the sedimentary province of the Gulf Coast geosyncline. This most important structural feature was the location of considerable sedimentation of clastic material during the entire Tertiary period.

The facies problems of the Eocene formations ranging from Wilcox to Cockfield are discussed and illustrated by cross-sections through the Chenyville, Eola, Ville Platte, and Mamou fields. The structural type, the different producing formations, and the reservoir characteristics of these fields are briefly described. Petroleum accumulation in these structures appears to be controlled by the presence of several marine shale bodies, which act as effective seals and cause the present distribution of petroleum in sand reservoirs underlying them. A possible relationship between oil types and sedimentary facies seems to be indicated, heavier hydrocarbons being found updip in the shallow-water sand facies, lighter hydrocarbons in the downdip, more marine, shale facies of a producing formation. E. N. T.

2574. Shell sets Louisiana production depth record. Anon. *Petrol. Engr*, Apr. 1950, **22** (4), B-90.—1 Weeks Unit 2, 12 miles from New Iberia, southern Louisiana, produced 540 b.d. from 14,226 to 14,241 ft. C. A. F.

2575. Missouri oil production shows increase in 1949. Anon. *Petrol. Engr*, Aug. 1950, **22** (9), B-74.—32,027 brl were produced in Missouri in 1949, a slight increase over 1948 production. Approx ninety-nine wells were pumped but were not in continuous production. Total footage drilled, all with cable tools, was 15,573 ft. C. A. F.

2576. Completes Montana gas well. Anon. *Petrol. Engr*, Aug. 1950, **22** (9), B-74.—Harden 1, in Glacier County, Montana, was completed for 13,300,000 cu. ft. gas/day from a total depth of 2712 ft. Cut Bank was topped at 2665 ft. C. A. F.

2577. New test method raises output at Delhi well. Anon. *Petrol. Engr*, Apr. 1950, **22** (4), B-83.—1 Giomi, in the Blanco gas field, New Mexico, on test flowed 21,500,000 cu. ft. gas/day, after shooting, from the Point Lookout topped at 4723 ft. C. A. F.

2578. New Mexico pool found. Anon. *Petrol. Engr*, Aug. 1950, **22** (9), B-76.—1-A Brownfield, 15 miles north of the Denton pool, on test flowed 2 M.c.f. gas/day with 1870 ft oil from 9575 to 9734 ft. Pay is Lower Permian Wolfcamp limestone. C. A. F.

2579. Geology and occurrence of oil in Medina sand of Blue Rock–Salt Creek Pool, Ohio. J. F. Swain. *Bull. Amer. Ass. Petrol. Geol.*, **34** (9), 1874–86.—The Blue Rock–Salt Creek Pool of Ohio is one of the most important areas of Pennsylvanian grade crude oil to be developed in the Appalachian area in recent years. The principal oil sand is a thin sandstone lying directly upon the Queenston red shale of Upper Ordovician age.

The occurrence of the reservoir and the accumulation of oil found in it are believed to be the result of sedimentary processes rather than of migration and entrapment influenced by the structure of the region.

This paper presents a brief account of development, followed by the data of stratigraphy and structure from which this conclusion has been drawn and finally gives the author's interpretation of the sedimentary conditions relating to the formation of the

reservoir and the means whereby the crude oil may have been transferred to it from the source material. E. N. T.

2580. Carter completes dual test. Anon. *Petrol. Engr*, Apr. 1950, **22** (4), B-90.—1 V. H. Cherry, in Garvin County, Oklahoma, on test flowed 560 b.d. of 46° oil in 11 hr from the Hunton and Bromide sands. Total depth was 10,177 ft. C. A. F.

2581. Correlation of Bradford Third and Richburgh sands, Pennsylvania and New York. R. W. Harding. *Bull. Amer. Ass. Petrol. Geol.*, **34** (9), 1866–73.—The Bradford, Pennsylvania, and the Allegany, New York, oilfields extend approx 65 miles northeast and southwest.

The major oil-bearing sands of the Bradford and Allegany fields are found in the Devonian Chemung formation, which is about 2100 ft thick. It consists of interbedded and lensing sands. Throughout the area there are six prominent sandstone members which are also considerably broken with grey shale partings. These sandstone members are in descending order: Bradford First, Sugar Run, Chipmunk, Bradford Second, Harrisburg Run, and Bradford Third.

In addition to these six sand members, there are several distinct stray sand lenses which are locally prominent.

There has been considerable discussion concerning the stratigraphic relationship of the Bradford Third sand of the Bradford oilfield to the Richburg sand of the Allegany field. This study is an attempt, through the use of full-hole electric logs, to show that the Bradford Third sand is the stratigraphic equivalent of that lens or series of lenses known as the Richburg sand.

Surface geology is included, in the area described, as a further means of substantiating the correlation of the Bradford Third-Richburg horizon. E. N. T.

2582. Directional permeability and dimensional orientation in Bradford Sand. J. C. Griffiths. *Producers' Monthly*, June 1950, **14** (8), 26.—Measurement of the long-axis orientation of quartz grains in thin sections of sand cores from the Bradford Sand, Pennsylvania, has shown that there is a grain orientation which is sensibly parallel to the direction of maximum permeability in these cores.

The chief grain orientation lies at an angle of about 30° to the bedding, and is best seen in sections perpendicular to the bedding and in the plane of max permeability. Solid reconstruction, based on three mutually perpendicular sections, suggests that the max permeability is parallel to this 30° imbrication rather than parallel to the bedding direction. C. A. F.

2583. New reef zone field. Anon. *Petrol. Engr*, Aug. 1950, **22** (9), B-78.—1 Willard, 1 mile west of the Adair field, Terry County, West Texas, on test flowed 144 brl oil in 4 hr from 8480 to 8507 ft. G.O.R. was 431 : 1. C. A. F.

2584. Good Snyder wells in. Anon. *Petrol. Engr*, Aug. 1950, **22** (9), B-74.—1 McLammy in the Snyder field, Scurry County, Texas, flowed 2739 b.d. from a total depth of 7008 ft.

6 Parish, in the same field, flowed 1527 b.d. from the Upper Strawn and 385 b.d. from the Lower Strawn from a total depth of 7502 ft. C. A. F.

2585. Oil and gas accumulations controlled by sedimentary facies in Upper Cretaceous Newcastle sandstone, Wyoming. H. E. Summerford, E. E. Schieck, and T. C. Hiestand. *Bull. Amer. Ass. Petrol. Geol.*, **34** (9), 1850–65.—The purpose of this paper is to deal with the problems of accumulation of oil and gas in the Newcastle, Wyoming, sandstone. Alternating facies changes from shale to sandstone appear to be the chief factors in localizing the traps.

Problems of accumulation of oil and gas in the Newcastle sandstone (Upper Cretaceous) involve facies changes from shale to sandstone which are recognized most clearly in the Mush Creek and Skull Creek area. Well-sample and electric-log information from 200 wells in the area has afforded details for classifying five sand beds which underlie the datum bed at the top of the Newcastle sandstone. The structure on outcrops and on the subsurface datum bed is a monoclinal, southwest dip of approximately 2°, formed in late-Cretaceous time (Laramide orogeny). The type log describes

the lithologic character of the five sand beds and shale inter-beds. Cross-sections and lithofacies maps of the respective sand beds illustrate the facies changes in the Newcastle sandstone. The accumulation of oil in the area is directly related to the porosity, permeability, and thickness of each sand bed. E. N. T.

2586. Three years of intensive development. J. L. Irwin. *World Petrol.*, July 1950, **21** (7), 26.—Leduc No. 1 found high-pressure gas in the Viking sand and topped the Devonian limestone at 4390 ft. There were shows of oil, gas, and water, and below 4995 ft porosity improved and testing began at 5066 ft. The well was brought in at 1000 b.d. in February 1947. Excellent production has been found at Leduc in the D2 and particularly in the D3 zones, and the field now has over 400 producers. There is a pipeline to Edmonton, where 16,200 b.d. are refined. Leduc covers 60 sq. miles. The Blairmore also produces oil.

In 1949 Alberta produced 20,246,466 brl of oil compared with 10,973,583 brl in 1948; in the first quarter of 1950 the output was 6,013,985 brl. The present market for Alberta's oil is 60,000–65,000 b.d., and this is likely to hold until the pipeline to Superior, Wisconsin, is completed.

Redwater was discovered in 1948, and produces from the D3 zone at about 3200 ft. It had 403 producers in May 1950. Reserves of 460,000,000 brl are indicated, the southern extension not yet having been properly tested.

Golden Spike also produces from the Devonian D2 and D3 zones. Open-flow potentials of 12,000 b.d. have been measured. Late in 1949 Excelsior was opened 12 miles north of Edmonton and has seven Devonian producers. Stettler, 100 miles south of Edmonton, is believed to have Devonian and Lower Cretaceous reserves of 100–150 million brl. A Devonian producer has been completed at Normandville, 220 miles northwest of Edmonton. The Lower Cretaceous produces oil at Campbell, 12 miles northwest of Edmonton. Malmburg No. 1, near Del Bonita, has given 240 b.d. from the Madison after acidizing.

Production at Lloydminster has been severely restricted, though it has been described as the "largest black oil" field of North America.

There are fifteen other oilfields in Alberta. G. D. H.

2587. Canada's early oil history. J. L. Irwin. *World Petrol.*, July 1950, **21** (7), 52.—The Athabaska oil-sand seeps have been known for 250 years. In 1830 oil seeps were noted near Enniskillen, Lambton County, Ontario, and in 1858 the first oil well was dug at Oil Springs. About a dozen wells were dug at Black Creek near Oil Springs, and in 1862 James Shaw drilled a well to 165 ft, which flowed oil. In an oil boom wells up to 2000 b.d. were completed. The wells were produced wastefully. Drilling costs were $3/ft for the first 500 ft. In 1864 Oil Springs had six refineries, but crude shortage caused the last to close in 1867. Developments continued at Petrolia. A refinery was built at London, Ontario, in 1880, and one at Petrolia in 1901.

Dry gas was discovered at Langevin in Alberta in 1885. The first well was drilled at Medicine Hat in 1890. Gas was found at Athabaska Landing in 1896 at a depth of 1200 ft. Later gas was discovered at Pelican Rapids. The Bow Island gas field was opened in 1900.

Oil seeps along Kishimena Creek near the Alberta–British Columbia border led to the drilling of a number of wells, one of which produced a little oil. Turner Valley was discovered in 1914, and this field has given over 100,000,000 brl. In 1924 the first well reached the Madison and obtained gas and distillate at the rate of 500 b.d. 1936 saw the first crude-oil producer from the Madison at 6828 ft. In two years Alberta's output reached near 7,000,000 brl/year; in 1942 it exceeded 10,000,000 brl, after which there was a decline. G. D. H.

2588. Preliminary report on Whitemud oilfield, Alberta, Canada. C. W. Hunt *Bull. Amer. Ass. Petrol. Geol.*, **34** (9), 1795–801.—The Whitemud area is 7 miles south of Edmonton, Alberta, and several miles east of the border of the Leduc–Woodbend field. It lies in slightly undulating plains topography near Whitemud Creek, a minor north-flowing tributary of the North Saskatchewan River.

The Whitemud oilfield produces Leduc-type high-gravity oil from the "Quartz Sand series" of the Lower Cretaceous.

Structure is believed to be anticlinal with stratigraphic conditions closely controlling

the position on structure of producible oil accumulations. Dips are extremely gentle and are thought to have originated from differential compaction of the Cretaceous rocks over irregularities on the eroded Devonian surface, as well as differential uplift in post-depositional time.

Possible ages and origins of the oil are discussed. E. N. T.

2589. Devonian nomenclature in Edmonton area, Alberta, Canada. Geological Staff, Imperial Oil Ltd. *Bull. Amer. Ass. Petrol. Geol.*, **34** (9), 1807–25.—The problem of establishing a practical terminology for a series of beds in which reef development occurs is highly complex. The rapid facies changes in the Devonian beds of the Edmonton area, coupled with a lack of diagnostic fauna, tend to make any classification subject to criticism. In the terminology proposed in this paper, the main object is to set up a series of easily recognizable lithological units which will be of practical value.

Geographic names have been given to four formations and seven members. Both electrolog and lithological characteristics of the various units are discussed. A type section for each newly named unit is described in detail. The areal extent of different lithologic units varies, and an attempt has been made to rank those units which are most widespread as formations and the more local units as members. For the purpose of this paper a restricted area of approx 10,000 sq. miles is designated as the preliminary region over which all of the facies, if present, are easily correlatable. With more well information the boundaries of this area will be extended to a greater or less degree, depending on the continuity of the unit in question. E. N. T.

2590. Preliminary report on Joseph Lake oilfield, Alberta, Canada. C. W. Hunt. *Bull. Amer. Ass. Petrol. Geol.*, **34** (9), 1802–6.—The Joseph Lake oilfield is 1 mile northeast of Joseph Lake in Alberta, Canada, which is 35 miles southeast of Edmonton, and produces high-gravity premium oil from the Viking sand of Cretaceous age. The structure of the field is regarded as anticlinal and to have originated from differential subsidence after Viking deposition. The age of the oil is discussed. E. N. T.

2591. Devonian stratigraphy, Sunwapta Pass area, Alberta, Canada. J. L. Severson. *Bull. Amer. Ass. Petrol. Geol.*, **34** (9), 1826–49.—The area with which this paper is concerned is in the vicinity of the national park boundary between Banff and Jasper national parks, Alberta. It is centred around Sunwapta Pass, which is the main pass over the Continental Divide in this part of Alberta.

Detailed sections involving Silurian and Devonian rocks were studied from the Nigel Peak area on the north southward to the Sunset Pass area.

The Mt Wilson quartzite, heretofore referred to the Devonian, is shown to be Ordovician or Silurian in age and a probable correlative of the Wonah formation of British Columbia.

The Devonian consists of three formations, the coral-bearing Fairholme at the base, followed by the scarp-forming Palliser limestone, and capped by the Exshaw shale and limestone. Tentative correlations are made between the Leduc section and the Sunwapta Pass area for Devonian rocks.

Mississippian Banff shale rests unconformably on the Exshaw formation.

E. N. T.

2592. Make two Canadian strikes. Anon. *Petrol. Engr*, Aug. 1950, **22** (9), B-76.—Liebing 8–24, 15 miles east of the Stettler field, Calgary, Alberta, flowed 2,675,000 cu. ft. gas/day from the Lower Cretaceous from 4125 to 4208 ft.

Sunnybrook 1, 15 miles southwest of Leduc, on test flowed 71,000 cu. ft. gas/day from the D1 from 5695 to 5717 ft. C. A. F.

2593. Discovery and development of oilfields in Western Canada. H. R. v. Gaertner. *Erdöl u. Kohle*, 1950, **3** (7), 305–13.—The prospective oil territory in Western Canada has an area of $2{\cdot}3 \times 10^6$ sq. km. and is bounded on the west by the Rocky Mts and on the east by the pre-Cambrian of the Canadian Shield. The general geological setting and stratigraphy are briefly discussed and some details given of oilfield developments in the foothills and plains. It is pointed out that in spite of all the shows and previous discoveries, Canada would not have attained its present importance as a producing

country but for the discovery of the productive Devonian reef limestone first found at Leduc in 1947. The further discovery in 1949 of Devonian oil at Normandville, south of Peace River and 300 km from the other fields in the Edmonton area, encourages hopes of a great areal extent of the oil-bearing reef limestone. The Norman Wells field and the Athabaska tarsands are also briefly described.

A close analogy is drawn between the geological conditions of Western Canada and those of Central Europe, and on this basis interesting European areas are indicated.

The difficulties involved in the development of the new Canadian fields are discussed.

S. E. C.

2594. Western Canada's oil and gas potentialities. T. A. Link. *World Petrol.*, July 1950, **21** (7), 40.—The Interior Plains sedimentary basin of Western Canada covers about 800,000 sq. miles. The provinces control most of the subsurface mineral rights in this area. In 1949 Canada completed 262 exploratory wells, fifty-eight being successful, thirty-seven obtaining oil, and two distillate. The wells aggregated 1,230,563 ft. The percentage success was similar to that in the U.S.A.

Most of the recent discoveries in Western Canada have been associated with Devonian reefs. Both Leduc and Redwater were discovered after seismic-reflection surveys, and this is also true of Excelsior, Bon Accord, Golden Spike, Stettler, and Normandville. But not all seismic anomalies have led to oil or gas discoveries, because stratigraphic as well as structural conditions need to be favourable. On some weak anomalies the D.3 zone has given only water. Regional geological studies are important, as well as adequate coring, testing, and logging. Oil shows have been noted in the Cambrian, Devonian, Mississippian, Triassic, Jurassic, and Cretaceous at the surface or at depth. The Devonian seems to be the most prolific oil formation, with the Mississippian second. There are both structural and stratigraphic traps. Almost all the Cretaceous pools are due to sand pinch-outs; Leduc, Redwater, Excelsior, and Norman Wells are coral-reef stratigraphic accumulations.

To the end of 1949 about 3000 wells had been drilled in Alberta, 1900 being in proved oil and gas fields. The reserves found range 1500–2000 million brl of oil and 7 trillion (U.S.) cu. ft. of gas.

Maps show the main outcrops and sedimentary basins and the general structure in Alberta. A regional section crosses British Columbia to Manitoba, while there are detailed sections of Leduc and Turner Valley. A graph shows the annual production since 1943 and the important discovery dates.

G. D. H.

2595. Tables summarizing activity in the search for oil in France, and French possessions. Anon. *Rev. Inst. franç. Pétrole*, June 1950, **5** (6), 195–8.—Tables give monthly for the second half of 1949 the numbers of oil, gas, and dry wildcat and development wells and the footage drilled in France and French North Africa; a summary relative to each field with the name, date of discovery, numbers of flowing and pumping wells, depth of producing horizon, daily output, at the beginning of July 1950, cumulative output to that date, number of wells drilling, the oil gravity and base, and the type and age of the producing formation; the numbers of wildcats and development wells planned for the first half of 1950.

G. D. H.

2596. Exploration in Italy extending into central and southern areas. Anon. *World Oil*, Sept. 1950, **131** (4), 276.—Exploration in Italy is being extended from the Po Valley into central and southern Italy. A wildcat is being drilled in the Porto Reconati area south of Ancona.

Exploratory drilling is said to be in progress in the Chiente Valley, Marches. Gas has been found near Aquila, Abruzzi.

North of Modena, Emilia, a well was completed for an initial production of 15 b.d. from 4950 ft.

The refineries at Bari and Leghorn are to be expanded.

C. A. F.

2597. The undeveloped oil reserves of Turkey. E. P. Lorenz. *World Oil*, Sept. 1950, **131** (4), 261.—The Ramandag field in Turkey is believed to be a continuation of the Kirkuk field in Iraq, and this trend may extend through Anatolia to the Dardanelles and Galicia. Oil seeps have been found in central and western Turkey, where there are many salt deposits.

There has been little exploration and drilling except in the Ramandag field, developed about three years ago. Turkey's annual consumption averages 2,808,000 brl, and its present production just exceeds 1 million brl.

All mineral deposits in the country are vested in the government, and there will be no major development of the nation's resources until foreign operators and capital are admitted. C. A. F.

2598. Studies of Roumanian oils. H. Hlauschek. *Erdöl u. Kohle*, 1950, **3** (7), 315–17.—The geological setting of the South Roumanian oilfields is described. The Flysch is petroliferous along its whole length from Ploesti to Vienna, and occasionally it includes Oligocene. Along the Alpine front the Molasse is petroliferous in place of the Flysch, which there is practically free of oil, and the Oligocene occurs only in the Molasse. The Miocene of the Carpathian foreland is practically free of oil. The Meotic has oil wherever geological conditions are favourable for accumulation. In neighbouring lands the transgressive Pliocene carries oil. Oil in the Dacic is confined to the mountainwards structures of the Ploesti basin.

Some 300 crude oil samples were distilled by the Hempel method, and their correlation index and average specific gravity of the last six fractions were determined. It was found that the Meotic oil was sharply differentiated from the Dacic, whilst the Miocene oil more or less resembled the Meotic oil from the same field. The Oligocene oil was of various types. The Meotic oil, the only type for which there are sufficient data available, showed no relationship between depth and average specific gravity.

In a discussion of the significance of the various types of crude oil, it is concluded that there is no ground for assuming that transformations from one chemical type to another have taken place. Furthermore, we know too little to be able to ascribe such differences to variations in the source material. S. E. C.

2599. Some recent additions to stratigraphy of Western Australia. C. Teichert. *Bull. Amer. Ass. Petrol. Geol.*, **34** (9), 1787–94.—Since 1947 there has been considerable geological activity in many parts of Western Australia, and knowledge of the distribution of several of the geological systems has been greatly increased. The author has been associated with many phases of this work either in the field or as palaeontological consultant to field parties in areas which he was unable to visit. Recent progress is chiefly due to surveys undertaken by the Australian Bureau of Mineral Resources, Geology, and Geophysics, and to reconnaissance carried out for the Vacuum Oil Co. and Zinc Corpn.

Important recent contributions to the stratigraphy of Western Australia include: discovery of Middle Cambrian; re-interpretation of Devonian stratigraphy in northern Desert basin; discovery of marine Devonian and Carboniferous in Northwest basin; re-investigation of Permian in Northwest and Irwin River basins; discovery of Middle Jurassic and eastward extension of boundary of Upper Jurassic in Desert basin; discovery of Tertiary rocks near eastern margin of Northwest basin. Miocene laterite has been discovered in the Northwest basin. E. N. T.

Geophysics and Geochemical Prospecting

2600. Recent advances in geophysical prospecting. J. M. Bruckshaw. *Petroleum*, Jan. 1949, **12** (1), 3–7.—Advances are the adaptation of existing methods to new environments rather than development of fundamentally new methods or greatly improved instruments. Geophysical examination of water-covered areas is very important. For this, use of sensitive, static-gravity meters is preferred, either based on rigid platforms above the water, in diving bells, or as remote-controlled meters. Fixing of positions is by land bearings or by application of radar techniques.

The use of helicopters is suggested and the principle of the airborne magnetometer described. This method has an accuracy comparable to standard field instruments for ground operation and has many advantages such as speed, less cost for large areas, elimination of local magnetic variations, etc.

Seismic methods for water-covered areas are similar to land methods but with geophones conveniently suspended from buoys for towing purposes.

The telluric current method, which is applied to the investigation of deep-seated

basement rocks, is explained. Equipment is relatively simple, and results are superior to the gravitational method but not so precise as the seismic-reflection method.

R. E. P.

2601. Geophysical prospecting in Western Canada. A. J. Barthelmes. *World Petrol.*, July 1950, **21** (7), 47.—The western Canadian basin has oil in pinch-outs, gentle closed structures, highly folded and faulted structures, and coral reefs. Magnetometers and gravity meters have been used for reconnaissance in this area, and seismographs for detail.

The Athabaska tar sands constitute the world's largest known oil accumulation (estimates of 300,000,000,000 brl have been made). The oil is in Cretaceous sands but may have come from the Devonian. There are Upper and Lower Cretaceous sand pinch-outs to the west, while the Madison and Devonian pinch-out against the Cretaceous. It is believed that the seismograph may be able to detect these, possibly by isopach studies. There are relatively few gentle closed structures. Those known are small and have given little production. The seismograph can locate the strong folds and faults in the foot-hills, but special skill is needed to interpret the data, because unique solutions do not necessarily arise. The dips may be discontinuous. The seismograph has revealed reefs, and experience in Illinois and West Texas has assisted. Isopach studies and dips are helpful.

The problems of seismograph work are discussed. In muskeg country operations were restricted to winter months to facilitate movement, though now light-weight equipment has made summer work possible. This year ninety-six seismograph parties are at work. Present geophysical expenditure exceeds $1,500,000 per month.

G. D. H.

2602. Alberta, Canada, gets aerial magnetometer survey. Anon. *Petrol. Engr*, Aug. 1950, **22** (9), B-78.—A large-scale airborne magnetometer survey is to be carried out in northwestern Alberta. The aerial method is especially useful in Alberta, where the greater part of the area is heavily forested and ground exploration slow.

The survey will be flown at 1000 ft in a series of parallel traverses spaced at 1½ miles. Over 16,000,000 acres will be mapped. C. A. F.

2603. Airborne magnetometer survey completed in North Tunisia. Anon. *World Oil*, Sept. 1950, **131** (4), 274.—Approx 20,000 sq. km. were flown in the airborne magnetometer survey completed in North-central Tunisa during the summer of 1950.

Using the Gulf airborne magnetometer, a record was obtained accurate to intensity variations of 1 γ. C. A. F.

2604. The Radiactivity of sediments (1). E. N. Tiratsoo. *Petroleum*, Mar. 1949, **12** (3), 61–5.—A laboratory method of estimating the radioactivity of rock samples is described, which should prove of value in establishing oilfield correlations, since this technique may easily be used in the examination of bit cuttings.

Earlier methods, utilizing ionization chambers and Geiger–Müller tubes, were too time-consuming, and usually needed large amounts of rock. This method needs only small quantities (10–20 g) of rock, and the time is a matter of minutes.

Powdered samples passing through a 60-mesh screen were sealed in bottles for a month before examination. A true sample of all the rock is obtained, and a month is sufficient time for radioactive equilibrium to be re-established. A Geiger–Müller tube with a glass skirt was used so that a homogeneous thin layer of the substance could be introduced round the active surface of the tube, and since the layer was thin the adsorption of γ-rays was a min. In general, three 10–20-min counts were taken using a counting apparatus. The sample was then tipped out and weighed. Details are given of corrections and accuracy of laboratory determinations. A number of rock samples have been examined and their comparative radioactivity indices

$$\left(\frac{\text{true increase of count per minute}}{\text{weight of rock}}\right)$$

given. R. E. P.

2605. Reflection seismic survey near Cuxhaven. G. Müller-Deile. *Erdöl u. Kohle*, 1950, **3** (5), 214–16.—The first detailed investigation of structures stretching far out

into the shallow sea (Wattenmeer) at Cuxhaven was undertaken in 1949, using the reflection-seismic method of survey. . The difficulties and methods of working in shoal water and on mud flats at various states of the tide are outlined.

The Cuxhaven–Spieka structure belongs to the numerous lines of salt and diapiric structures which extend across Schleswig-Holstein in a Rhenish direction and in some cases continue south of the Elbe. The structure of the east flank was known from previous reflection surveys; the present work, thanks to numerous good reflecting horizons, gave a very clear picture of the geology of the west flank. The west flank is separated from the top zone by faulting or other marginal disturbance, whereas the passage from the presumably highly disturbed top zone to the east flank is apparently unbroken. The earlier view, based on refraction work, that there are two separate structures, is untenable, and it seems probable that there is an asymmetric anticline, with Permian core and blanketed with more or less thick Quaternary beds, which extends in a broad arch from the Weser to the Elbe estuary. On the other side of the Elbe, on the same line, is the Marne–Heide–Hennstedt range of structures from which oil production has been obtained. S. E. C.

2606. The determination of true dip and depth of strata. A. Langhammer. *Erdöl u. Kohle*, 1950, **3** (5), 217–18.—(See Abs. No. 1401).—Krouskij's method for determining true dip and depth of seismic-reflecting horizons involves an extrapolation which is not always valid. The author describes a method, used by Seismos G.m.b.H. since 1943, to overcome this difficulty. S. E. C.

2607. A circuit for firing seismic blasting caps. W. I. Duvall. *U.S. Bur. Mines Rep. Invest.* No. 4705, July 1950.—When using the gauge and recording equipment for measuring dynamic strain in rock, described in *Bur. Mines Rep. Invest. No.* 4581, 1949, difficulty was experienced from spurious vibrations that appeared on the records at the time of detonation. The cause is explained, and an improved electrical circuit is described which eliminates the difficulty. Reference signals are generated at the time the current starts flowing in the cap circuit and at the time the cap detonates. These reference signals can be used to determine the firing-delay time of siesmic caps and the time at which the seismic wave is generated by the explosion. W. H. C.

Drilling

2608. Equipment and techniques for 20,000 ft drilling. P. M. Payne. *Petrol. Engr Ref. Ann.*, 1950, **22** (7), B-3.—See Abstract No. 417. C. G. W.

2609. Wild-catting in Florida. J. E. Banks. *Oil Gas J.*, 22.6.50, **49** (7), 252.—A thick blanket of cavernous and irregularly bedded limestone and a basement complex of sedimentary and igneous rocks has made the search for oil and gas difficult. Distance from supply and service centres has had a considerable effect on drilling costs. Drilling conditions in various parts of Florida are described. The most common drilling hazard has been loss of circulation in cavernous limestone. In these regions drilling with no returns is a common practice, though difficulties are encountered when cavities are too small to take drill cuttings. C. G. W.

2610. Systematic development followed in Alberta's Stettler oilfield. P. C. Ingalls. *Oil Gas J.*, 20.7.50, **49** (11), 70.—The early exploration programme in this field is outlined. There is no free gas in the reservoir, and no excess gas or water is produced.

Mud problems are not excessive, one zone requiring treatment for anhydrite, salt, and shale contamination, while in another zone fluid loss occurs. An experiment is being conducted on dual completions. C. G. W.

2611. States report on offshore drilling in Louisiana. A. L. Vitter, Jr. *Oil Gas J.*, 22.6.50, **49** (7), 221.—Twelve oilfields and eleven gas fields have now been discovered. Brief data on some of the fields are given. C. G. W.

2612. Adjusting casing after cementing for stress control at the freeze point. B. E. Curran. *Petrol. Engr*, Aug. 1950, **22** (9), B-7.—After a string of casing has been cemented it is not necessary for the free length of the string to support the load due to

the frozen section. The stress in the free length can be adjusted as desired by slacking off or picking up the casing string at the surface. Generally it will be desired to maintain a tensile stress at the freeze point. The magnitude of the tensile stress will be determined by the temp variations expected, plus a margin for safety. This tensile stress is necessary to prevent the development of compressive stresses and consequent buckling. Equations are developed for determining the stretch of casing strings taking into account the effects of buoyancy and lateral pressure. Total stretch is given by the equation :—

$$S = \frac{l^2}{2E}[\delta - 2w(1 - \mu)]$$

where
S = total stretch ;
l = total length of casing string ;
δ = density of steel ;
w = density of fluid ;
E = Young's modulus ;
μ = Poisson's ratio.

It is shown that under the conditions for which this equation is developed there is a point of zero stress at some intermediate position in the casing string.

The effect of temp on the stress in the column is discussed and evaluated. The equations so far developed are combined to give a relation between the necessary pick up or slack off at the surface and the desired tensile stress at the freeze point. Adjustment at the surface in inches is given by the relation

$$\Delta e = \frac{144a}{E}[\delta b - w] - \frac{12Sa}{E}$$

where
e = surface adjustment inches ;
a = free length of casing ft ;
b = frozen length of casing ft ;
δ, w, and E as before ;
S = desired stress at freeze point.

A graphic solution of a form of this equation is presented enabling the necessary surface adjustment to be determined directly. The derivations of the equations for the stretch of casing freely suspended in fluid, for the determination of the position of the neutral point, and for stretch of casing suspended in fluid and fixed at lower end are presented in three appendices.

References are appended. C. G. W.

2613. Use of bottom plug in cementing operations. H. F. Hopkins. *Oil Gas J.*, 22.6.50, **49** (7), 308.—The present practice of running two cementing plugs is designed to achieve two results. One is to clean the pipe ahead of the cement column, and the second to prevent mixing of cement and drilling fluid being flushed ahead of the cement.

In areas where pipe freezing is a danger any stoppage of circulation should be avoided, and surface equipment with a double-plug-type plug container is satisfactory. C. G. W.

2614. The time factor in cementing. B. Barkis. *Petrol. Engr, Ref. Ann.*, 1950, **22** (7), B-70.—See Abstract No. 1424. C. G. W.

2615. Blowouts in California drilling operations. A. J. Horn. *Oil Gas J.*, 27.7.50, **49** (12), 289.—An investigation has been conducted on the blowouts which have occurred in California in recent years. Blowouts occur when control of the formation pressure is lost and surface blowout equipment fails. Primary control is effected by means of the fluid column and loss of control may occur by (1) lost circulation, (2) insufficient fluid density, (3) reduction in static head by pipe withdrawal, (4) failure to keep the hole full. It should be noted that lost circulation may be induced by high-density fluid, or by " running-in " pressure. Failure of a weak formation, with consequent loss of returns, may occur.

All blowouts were attributable to one or other of the above causes, and the frequency of occurrence from each cause is analysed. A majority of the blowouts occurred on

exploratory wells. Some of the blowouts on development wells were attributable to gas-cutting of the mud.

Loss of secondary control may be due to: (1) insufficient control equipment, (2) improper design of equipment, (3) improper installation of equipment, (4) improper surface fittings, (5) improper well-casing programme and cementing practice.

The proportions in which failures are due to these causes are determined. Detailed procedures are presented for maintaining proper primary control during all phases of the drilling operation. The proper selection, installation, and operation of control equipment is advised.

References are appended. C. G. W.

2616. Radioactivity well logging in Canada. S. W. McGaha. *World Oil*, Sept. 1950, **131** (4), 266.—Radioactivity well logging, using γ-ray and neutron curves, has been used successfully in recent years in Western Canada. The method has been used in new wells and in old cased wells where it may be necessary to check zones.

The response of the curves to different rock types is described, and examples of their use in correlation are given. C. A. F.

2617. Micrologging in west Texas and New Mexico. A. Morazzoni and W. J. Lytle. *World Oil*, Sept. 1950, **131** (4), 127.—The " microlog " has been used in the Permian basin since 1949, chiefly for the selection of perforation intervals and the determination of net pay thicknesses for reserve estimations. It may be possible in the future to estimate porosity from the log.

The method was developed primarily to pin-point permeable beds where the SP log is inconclusive. It has been found to be particularly useful in limestone pays, such as are found in the Permian basin, in west Texas and New Mexico.

The " microlog " is a resistivity log, recorded with short-spaced electrodes enclosed in an insulated pad in contact with the walls of the hole. Two electrode spacings, 2 in and slightly less, are commonly used to give two depths of investigation. Both curves are recorded simultaneously.

In logging limestones, impermeable beds generally show high resistivities, and permeable beds much lower. Low resistivities are also recorded opposite shales and in caved holes, where the electrode pad does not touch the walls and the electrodes are short-circuited by the mud. Where low-resistivity sands are present it is not easy to differentiate them from adjacent shales.

Examples of micrologs are included, and two references are given. C. A. F.

2618. Revised mud system features unusual design innovations. Anon. *Oil Gas J.*, 20.7.50, **49** (11), 102.—The drilling fluid is circulated and conditioned in steel tanks, a piping service system being welded round the top of each. System is further described by photographs. C. G. W.

2619. Mud materials as tools for the drilling industry. O. W. Van Dyke. *Oil Gas J.*, 27.7.50, **49** (12), 220.—As drilling depths increase the mud programme becomes more important and the cost of mud materials a more significant part of drilling costs. Many such mud materials are designed to serve a single specific purpose, and may be regarded as tools. Mud materials are available for handling every type of drilling problem yet encountered. The possibilities of mud treating are now being realized. Functions of a satisfactory drilling fluid are outlined, and the available additives and types of mud in use are enumerated. C. G. W.

2620. Out of the war a new method of rig skidding. C. Thompson. *Petrol. Engr*, Aug. 1950, **22** (9), B-15.—A method of moving rigs up to 1000 ft in 15 min, using tractor wheels, heavy steel and timber beams, and 225-ton hydraulic jacks is described by means of captioned photographs. C. G. W.

2621. New remote control rig. R. F. Carlson. *Oil Gas J.*, 29.6.50, **49** (8), 74.—All rig operations including engine throttle, clutches and drives, speed changes, and brakes are remotely controlled from a movable-type control panel. Other features are independent rotary and catshaft drive unit and low engine substructures permitting drawworks to be located below level of derrick floor. C. G. W.

2622. Sun's seadrome. E. A. Armstrong. *Oil Gas J.*, 22.6.50, **49** (7), 192.—This new offshore structure is described as a self-docking, jet-manœuvred variable-draught floating offshore rig. It is made up of eight buoyancy tanks in two rows of four, framed into a supporting truss structure. With the structure in place the buoyancy tanks rest on the ocean floor. To assist in lifting the structure off bottom on completion of a job, jets are so arranged that a radial stream of water washes over the tank bottom. These jets are also of assistance in levelling off a foundation site and in manœuvring the rig over a well site. The structure can be propelled by the jets alone at a speed of 3–4 knots. The deck structure is coupled by a hydraulic jack system to foundation columns mounted on the buoyancy tanks. Lifting of the deck structure by the jack system requires four lifting and four holding jacks on each column. The jacks are operated manually by power, all columns together or singly. Adjustments of the jack system, if necessary aided by use of the jets, enables the load to be distributed uniformly over the foundation column tanks.

The rig is completely self-contained for drilling to 16,000 ft. It is claimed that the rig can operate in depths from 12 to 80 ft of water, with modifications to depths of 120 ft, and that drilling can proceed regardless of weather conditions. C. G. W.

2623. Ocean waves and marine oil operation. D. F. Leipper. *Oil Gas J.*, 22.6.50, **49** (7), 214.—There are two ways in which offshore structures may be altered to withstand the damaging effect of hurricane waves. One is to strengthen the structure or reduce its wave resistance, the other is to raise the platform above the zone of wave action.

It is now generally agreed that : (1) major forces causing damage are the vertical forces associated with ocean waves, (2) elevation of platform decks above the zone of action is the best means for preventing damage in hurricanes, (3) information on ocean waves and oceanography is necessary, (4) the Sverdrup–Munk wave theory is probably not applicable to hurricanes in the Gulf coast continental shelf area, (5) the standard weather forecast is inadequate for the offshore operator.

The primary problem facing the offshore operator is the determination of the probable max elevation of wave crest above bottom. Secondary problems concern the forces exerted by waves on the platform structure below deck. Although present structures are satisfactory, further knowledge of the forces associated with waves can improve the design of such structures.

These problems can be answered only by the development of an adequate oceanographic theory consistent with and supplemented by geological, meteorological, and oceanographic data. The necessity for close co-operation between oceanographer and marine engineer is emphasized.

The manner in which oceanographic research is organized is outlined with particular reference to the work of Sverdrup and Munk. The limitations of the theory developed by these authors when applied to hurricane conditions are mentioned.

Problems of particular interest in this area are : the applicability of model studies and force distributions in waves.

Completion of statistics, including observations at offshore sites, will assist the ultimate solution of such problems, particularly if offshore operators co-operate to produce complete and up-to-date information. C. G. W.

2624. Wave, tide, current and hurricane problems in coastal operation. A. H. Glenn. *Oil Gas J.*, 22.6.50, **49** (7), 174.—Wartime developments in meteorology are now applied to problems in offshore drilling. A forecasting service now in operation includes a forecasting office in New Orleans ; a coastal weather- and wave-observing network and a radar observing station ; and a climatological office in Washington. Communications are by radio and teletype services. Supplementary information is obtained from observations made from drilling rigs. Twice daily advisories are given of routine wave, wind, and weather forecasts for periods 0–48 hr. Special advisories are given of hurricanes and squalls and of conditions which may lead to severe storms. In addition to advisories, discussions between meteorological and oilfield are of extreme importance in determining measures to be taken.

Of all problems involved in prediction, those concerning wave forecasting are nearest to solution, and a table is presented indicating the effect of waves at various offshore operations. Accuracies of predictions are high, varying from 75 to 95% in reliability.

Problems involving wind, tides, and currents present great difficulties, but are being tackled.

Twenty-three references. C. G. W.

2625. Louisiana and Texas offshore operations. H. C. Cortes and R. N. Gsell. *Petrol. Engr*, Sept. 1950, **22** (10). B-7.—It is stated that Louisiana and Texas Gulf waters contain one of the best oil and gas reserves in the U.S.. Geophysical and drilling methods are briefly described and the legal aspects of offshore drilling outlined. C. G. W.

2626. Note on the flexing of a heavy vertical column submerged in a liquid : application to drill-pipe. G. Lugol. *Rev. Inst. franç. Pétrole*, Feb. 1950, **5** (2), 27–32.—In drill-pipe the weight is of importance with regard to the flexing. Figures have been derived to show the lengths of drill-pipe and drill-collars of different dia which are needed for flexing to occur in air, and these lengths increase with the dia. This flexing is to be avoided if possible, because it leads to rapid wear. It may not be practicable to avoid the wear on drill-collars, though there the greater thickness of metal is an advantage. To avoid flexing, tension must be maintained on the drillstem. The conditions are more complex in a hole full of mud, and the problem arises as to the effects of the displaced mud on flexing. The drill-pipe behaves with regard to flexing as though its apparent weight in the mud is the effective weight. It is also concluded that it is useless to increase the weight of the drill-collars to offset the effects of the mud. The problems are analysed mathematically. G. D. H.

2627. A study of the action of rock bits. H. Besigk. *Erdöl u. Kohle*, 1950, **36** (6), 257–66.—Object of this study of cone- and roller-type rock bits is to stimulate the interest of both the practical driller and the manufacturer in the manner of action of the bits and the factors affecting their performance. A formula is developed for the calculation of drilling rate for cone-type bits, and from this and experimental work the individual factors affecting performance are deduced. It is shown how the life of these bits and also the economic rate of rotation and amount of weight for conditions in a given oilfield can be estimated. Although no two bits are exactly the same and field conditions vary to some extent from well to well, the limits of these deviations can be determined. S. E. C.

2628. Effect of temperature, pressure and stand-off upon perfo-jet penetration. J. E. Reed and F. F. Carr. *Oil Gas J.*, 3.8.50, **49** (13), 69.—Experiments on the effects of variables on penetration of shaped charges have been carried out in a model well. The well is a 26 ft tube, inside dia $15\frac{1}{8}$ in, walls $6\frac{5}{8}$ in laminated steel. The apparatus can be operated at conditions up to 15,000 p.s.i. and 350° F, pressures and temps being controlled and measured. 21-g shaped charges were exploded and the penetration of a number of $\frac{1}{2}$-in mild-steel plates recorded for a series of pressures, temp, and stand-offs, the stand-off being defined as the distance between the charge and the object being penetrated.

It was found that temp and pressure had no effect on penetration but that max penetrations were obtained with stand-offs below 2 in. C. G. W.

2629. Selecting the drill stem. B. Schabarum and S. Moore. *Petrol. Engr*, Aug. 1950, **22** (9), B-62.—Present trends in contract drilling are towards more economic operations, particularly in selecting equipment for the work to be done. There appears to be a basic relation between available horse-power, drill-stem size and depth, and dia of hole to be drilled. Rig horse-power requirements are generally estimated as 1 h.p. per 10 ft of depth. It is claimed that there is little time or horse-power saving with slimhole drilling. The hydraulic efficiency of the system is considerably more important from the point of view of economic operation. At present about 65% of total power is used in pumping drilling fluid and from 80 to 90% of pump pressure is lost in the drill stem, drill collars, etc. It is claimed that it is possible to cut total power requirements by 30–40%. The problem of obtaining high hydraulic efficiencies is particularly important in jet drilling.

The internal dia of drill pipe is of considerable importance, since small changes in

dia have a great effect on power requirements. For example, a 2-in-bore drill collar requires twice as much power as a 2¼-in-bore collar for the same rate of flow.

A general increase in drill-stem dia is desirable for improved hydraulic efficiency. Elevator shoulders are responsible for a considerable loss in hydraulic efficiency. Tool joints of dia ¼ in larger than the drill stem and drill collars of large bore are recommended. Tables are presented of pressure losses with various dia and depths of hole and different types of drill stem. These indicate that in some cases power requirements can be cut in half.

References are appended. C. G. W.

2630. Use of tubing as drill pipe. W. F. Bates. *Petrol. Engr*, Aug. 1950, **22** (9), B-42.—See Abstract No. 1773. C. G. W.

2631. Rig to office communications. C. J. Paine and J. Stover. *Petrol. Engr, Ref. Ann.*, 1950, **22** (7), B-61.—The principal advantages claimed for radio communications on drilling rigs are : (1) saving on time waiting for orders, (2) saving on time for breakdown and repairs.

Incidental advantages are reduction of waste journeys with trucks and rapid and easy contact with field personnel.

A radio system generally consists of mobile units on trucks and cars, portable units on drilling rigs, and on office station. These units are briefly described. The importance of locating the office station in an area free from interference is emphasized. When necessary a station can be located in a " quiet " area remotely controlled from one or more locations.

Ranges obtainable are : car to car 20–30 miles ; rig to car 40–50 miles, rig to office 50–70 miles. By using directive antennæ the ranges can be increased up to 70 miles to cars and 100 miles to rigs.

The costs of operating radio communications are analysed and average figures given. C. G. W.

2632. Jet process of open hole shooting. W. T. Box. *Oil Gas J.*, 29.6.50, **49** (8), 85.—The shaped-charge process has two main applications in oil-well shooting. The first is in perforating casing, the second in open-hole shooting.

The advantages of jet perforating in open-hole shooting lie in deep penetration and fracturing of formation without increasing the well bore excessively and without plastering and sealing the sand face. Greater accuracy, flexibility, and selectivity are also obtained. The method may also be applied to wells previously shot with bulk charges and to cased wells. In the first of these applications caliper surveys will indicate the most promising zone for shooting. In the second case cracking of the casing is likely to occur.

Glass-sealed and lined charges have been used, but the charges now in general use are copper lined and entirely sealed from the well pressure. These charges are of 2 in dia, the liner angle being varied for two lengths of charges 4½ and 5½ in. The charges are supplied ready to fit into pressure-resistant cases of plastic, aluminium, magnesium, or cast iron. Aluminium and cast iron are used for high-pressure services. The charges have generally been mounted in a rigid light aluminium case, detonated by an explosive cord run along the back of the charge case. The cord detonates a booster charge at the back of the charge case. Cast-iron carriers have been used with some success. C. G. W.

Production

2633. Abqaiq—world's highest producer. P. Reed. *Oil Gas J.*, 3.8.50, **49** (13), 42.—This field is currently producing 450,000 b.d. from forty-five of a total of sixty-five wells. Studies are being carried out to determine the max efficient rate of production. Well depths are from 6000 to 7000 ft. Rigs are moved to new sites in four to five days on large dollies. Wells are spaced at 6000-ft intervals. The field appears to be a dissolved gas-drive with limited water influx. Pressure drop in 1950 has been 0·9 p.s.i. per 1,000,000 brl of oil. Wells are completed barefoot. Crude is stabilized before export. C. G. W.

2634. More wells—more oil. Part 1. H. H. Kaveler. *Petrol. Engr*, Aug. 1950, **22** (9), B-30.—Presents production statistics and related facts concerning six pools as typical examples of fifty pools that have been studied. It is emphasized that oil production depends directly on the available reservoir energy and that only sufficient wells are required to make the best use of available energy.

Wells are necessary : (1) to define the extent of the pool and limits of production, (2) to ensure that every segment of the pool capable of producing petroleum is penetrated by at least one well, (3) to ensure sufficient wells to permit the max beneficial use of either natural or artificial sources of reservoir energy, (4) to ensure sufficient numbers of wells to maintain productive capacity at rates equal to or in excess of market demand for petroleum.

Field histories in cases where accurate records have been kept have established certain conclusions. (1) A well is capable of draining an area of a common source of supply larger than the area attributed to its drilling or spacing unit. (2) The capacity to drain a large area of a common source of supply occurs in limestone and sandstone reservoirs. (3) Increased numbers of wells may decrease ultimate recovery of oil if excessive depletion of reservoir energy occurs by drilling into gas caps, high gas–oil ratio areas or into water tables. (4) For the greatest ultimate oil recovery wells must be drilled to penetrate every productive segment of a pool and to define the extent of oil pools. (5) Cutler's rule gives an empirical relationship for determining the amount of oil that may be drained from a common pool by separate leases drilled to different well densities. Production histories of two leases are given. C. G. W.

2635. More wells—more oil. Part 2. H. H. Kaveler. *Petrol. Engr.*, Sept. 1950, **22** (10), B-54.—Article concludes the discussion on the value of close well spacing and in-fill drilling. Field histories of three more fields are described and discussed.

Cutler's Rule states that " the ultimate productions for wells of equal size in the same pool, where there is interference (shown by a difference in the production-decline curves for different spacings) seem approximately to vary directly as the square roots of the areas drained by the wells." This rule, its limitations, and applications are discussed at length.

References are appended. C. G. W.

2636. Why do many geologists and engineers disagree on well spacing? J. G. Bartram. *Oil Gas J.*, 27.7.50, **49** (12), 216.—It is claimed that as a general rule, geologists favour close well spacing, whereas reservoir engineers prefer wider spacings. The major points of disagreement are : (1) the amount of reservoir energy required to move the oil horizontally through the reservoir ; (2) the continuity of porosity and permeability in the reservoir rock.

The advocates of wide spacing claim that only a small part of the reservoir energy is required to move the oil, and that porosity and permeability are much more uniform in reservoirs than is generally believed. Early theories of reservoir behaviour were based on Cutler's Rule and the Jamin Action, and these were advanced in favour of close well spacing. The effect of other variables on oil production makes statistical analyses unreliable. Such analyses merely indicate that other factors are more important than well spacing. Recent conclusions indicate that close spacing has a practically negligible effect on the ultimate oil production. It is emphasized that the production rate of oilfields should be controlled to give the most efficient pressure decline and that production should be taken from selected parts of the field.

Reservoir engineers are generally in favour of the widest possible well spacing consistent with adequate production rates, accurate reservoir data, etc. In-fill drilling can be carried out as necessary in cases where discontinuities are evident, etc.

Arguments put forward in this article are summarized. C. G. W.

2637. Oil well production stimulation. H. D. Daggers. *Petrol. Engr*, July 1950, **22** (8), B-44.—An important factor in production decline is plugging of liner perforations and formation by scale, mud, sand, silt, etc. Three methods of removing such plugging agents are : (1) mechanical cleaning of liner slots, (2) acid treatment of mud cakes, (3) combination of acidization and string shot.

Before instituting any remedial work it is important to select wells that are likely to respond to treatment and to select methods of treatment that appear applicable to the existing well conditions.

Mechanical cleaning is carried out by knife cleaners or rotary-wheel cleaners which are passed up and down through the perforated section. This treatment should be followed by swabbing and boiling.

Acid treating is effective where the formation contains acid-soluble material. The method of acidizing adopted depends on the bottom-hole conditions obtained.

The string shot consists of a single or double explosive primer cord equal in length to the perforated section. When this explodes the whole face of the lines and formation is cleaned. When the well is shot with a batch of acid in-place acidization at a moderate temp immediately occurs. The well should then be swabbed or pumped clear of acid and reaction products. C. G. W.

2638. Chart for the calculation of the net permeability of invaded reservoirs. J. G. Roof. *Petrol. Engr.*, Sept. 1950, **22** (10), B-78.—An equation is derived for calculating net permeabilities in concentric radial systems. This equation, which depends on the permeabilities in each of two concentric zones in contact at radius R_0 being constant but different, is :—

$$\text{Log Log}\,(r_0/r_w) + \log\left[\frac{1}{K_1/K_2} - 1\right]$$

$$-\log\log\,(r_e/r_w) = \log\left[\frac{1}{K_n/K_2} - 1\right]$$

K is permeability between well radius r_w and zone r_e.

A chart is prepared from this equation enabling direct determinations of permeabilities. C. G. W.

2639. Effect of oil-base drilling fluid filtrate on analysis of cores from South Coles Levee, Calif., and Rangely, Colo., fields. G. L. Gates, F. C. Morris, and W. H. Caraway. *U.S. Bur. Mines Rep. Invest. No.* 4716, Aug. 1950.—A study is reported of the contamination of cores cut by conventional core barrels while oil-base drilling fluid containing an organic tracer soluble in oil and insoluble in water was being injected. A theoretical material balance was made for probable changes in the fluid content of cores during coring operation. The test results call attention to new methods of obtaining cores and modified methods of analysing the cores and the resulting core data. W. H. C.

2640. Core analysis technique for limestone and dolomite. L. C. Locke and J. E. Bliss. *World Oil*, Sept. 1950, **131** (4), 204.—The non-homogeneity of limestones and dolomites precludes the sampling of these formations for porosity and permeability determinations by conventional methods. A new method has been developed whereby the entire core, rather than selected plugs, can be used to determine porosity and permeability.

The cores are cut in lengths up to 2 ft, extracted, and dried. They are then placed in a high-pressure cell and evacuated. On release of the vacuum, fluid is allowed to enter the cores, and the vol of fluid entering the cores until atmosphere pressure is reached is measured against time. Additional pressure to 1000 p.s.i., is then applied in small increments. The vol entering for each pressure increment and the corresponding times of entry are measured. The total vol injected is assumed to be the effective pore space, and the vol injected v pressure and time is a measure of permeability.

Permeabilities obtained by this method are non-directional and check closely with measured P.I. data. C. A. F.

2641. Reporting of routine laboratory core analyses for maximum utility. J. W. Young, A. S. McLatchie, and T. H. Martin. *Petrol. Engr*, Sept. 1950, **22** (10), B-71.—Suitable methods of core evaluation should : (1) provide the reservoir engineer with a summary of data in a readibly usable form, (2) present all basic figures in a form that will permit ready detailed checking and correlation with electrologs and other related data, (3) organize arithmetic data in a form that allows rapid check of calculations, (4) present derived data in a form that will allow a correlation of special tests.

Procedure adopted is as follows : The cores are described according to porosity and character of rock, the description being recorded by a system of code letters and numbers. They are then extracted with CCl_4 in a Soxhlet-type extractor and dried in an

oven. The cores are weighed, dimensions are taken by vernier caliper, and routine porosity and permeability determinations are made. These tests are followed by determinations of pore-size distribution and some chemical analysis of the rock and connate water by the restored-state technique.

The manner in which the results are reported is described. C. G. W.

2642. Some theoretical considerations related to the quantitative evaluation of the physical characteristics of reservoir rock from electrical log data. M. R. G. Wyllie and W. D. Rose. *Petrol. Tech.*, Apr. 1950, **2** (4), *A.I.M.M.E. Tech. Paper No.* 2852, 105–19.—Since electric logs are obtained in almost all wells, it is desirable to investigate the probabilities of deriving from them reliable information on the physical characteristics of the reservoir rock, since such derivation would reduce or eliminate coring and core analysis. Investigation of the problem shows that the cementation factor, formation factor, and resistivity index exponent are related to the rock texture parameters in the Kozeny equations and expressions of capillary pressure phenomena. It does not appear at present that electrical log data alone can give accurate estimates of the reservoir rock parameters, although a judicious combination of log data and selected core analysis data may often give expressions for certain of these parameters which have fairly wide applicability. The common relationship $F = \phi^{-m}$ has no fundamental significance, though the practical limits of m are likely to be 1·3–3·0. Assuming that tortuosity in fluid flow is the same as that in electrical flow the formation factor is shown to be $F = \frac{T^2}{\phi}$, where T is the tortuosity and ϕ the porosity.

Reservoirs in which m is independent of porosity are unlikely. The resistivity index is $I = S_w^{-n}$, and in this n is dependent on the texture of the porous medium and the wetting-liquid saturation, according to the inferences from investigation of the expression. At low wetting-phase saturations, however, n may range 1·7–2·5 in many practical cases, and so $n = 2$ is of considerable practical utility.

A formation factor of 5 seems to imply a porosity of over 20%, and a factor of 10 indicates porosity exceeding 10%.

Where Tixier's empirical relationship involving the capillary pressure is not applicable because there is no oil–water contact to give the latter factor, a correlation has been suggested between the irreducible water saturation and the formation factor to give the permeability. G. D. H.

2643. Plotting pressure drop against cumulative production of gas fields on log-log paper. H. A. Guy and J. A. Crichton. *Petrol. Engr*, Sept. 1950, **22** (10), B-76.—Sets out to clarify and establish the validity of certain principles applied in a previous paper by these authors. C. G. W.

2644. Central control of pressure maintenance project. C. K. Brown and W. D. Mason, Jr. *Oil Gas J.*, 22.6.50, **49** (7), 206.—A central control for a pressure-maintenance project, involving twenty producing and one gas-injection well, is described. The installation is designed for max flexibility, and is intended to last until the reservoir is depleted. C. G. W.

2645. The coexistence of liquid and vapour phases at pressures above 10,000 p.s.i. M. J. Rzasa and D. L. Katz. *Petrol. Tech.*, Apr. 1950, **2** (4), *A.I.M.M.E. Tech. Paper No.* 2809, 119–28.—Phase diagrams for six mixtures of methane and Kensol 16, with 15·78–75·78% by weight of methane have been prepared from data obtained at pressures up to more than 13,000 p.s.i. and temp up to 260° F in a windowed cell. Liquid and vapour phases were found to coexist at pressures above 10,000 p.s.i. The critical points for three of the mixtures were as follows :—

Composition (weight)	Crit. temp.	Crit. press.
49·80% methane	235° F	10,200 p.s.i.a.
52·00% methane	55° F	12,670 p.s.i.a.
52·10% methane	51° F	12,700 p.s.i.a.

A critical locus for the methane–Kensol 16 system was prepared, and equilibrium vaporization factors were estimated from the data and extrapolated to temp of 700° F.

In contrast to mixtures composed of substances of fairly close volatility, critical

opalescence was noted at as much as ±200° F from the critical temp. For mixtures of widespread volatility it is very difficult, if not impossible, to determine the saturation pressures by the conventional pressure–volume curves, even under conditions well removed from the critical point. Visual means appear to be the most reliable method of determining these transition points. The conclusion was reached that for binary systems the influence of wide differences in volatility is such that the max pressure on the critical locus is shifted towards the compound of highest volatility, with the shift becoming more pronounced as the volatility spread increases.

The data indicated that for well depths of the order of 12,000–15,000 ft it is not necessarily sound to assume that the reservoir fluid will be in a single phase.

G. D. H.

2646. The estimation of permeability and reservoir pressure from bottom hole pressure build-up characteristics. C. C. Miller, A. B. Dyes, and C. A. Hutchinson. *Petrol. Tech.*, Apr. 1950, **2** (4), *A.I.M.M.E. Tech. Paper No.* 2849, 91–104.—Mathematical treatment has led to relationships which permit the estimation of the effective permeability and the reservoir pressure from the early parts of the pressure build-up curve of a well stabilized before shutting in. Equations were derived for the flow of a homogeneous compressible liquid, and were extended to include an approx to the condition of intermingled oil and gas. The early part of the build-up curve is independent of the amount of migration over the external boundary, and this is used for the estimation of permeability. For max and zero migration over the external boundary the difference in final pressure may be significant, and hence it is necessary to assume a value for the amount of this migration in estimating reservoir pressure by this means. High production rates and low permeabilities both lead to increased uncertainty arising from estimation of the degree of migration. This error being practically constant, in succeeding determinations the pressure decline would be obtained with greater accuracy.

The presence of a zone near the well of higher or lower permeability than the rest of the formation leads to deviation from the equations. Studies with the electric analyser show that this deviation is appreciable only in the very early part of the curve. The permeability estimated from the build-up curve is that of the bulk of the formation away from the well. The productivity index gives an overall value, and comparison of the two values is a guide to the presence of high or low permeability near the well.

G. D. H.

2647. A simplified method for the design of rod pumping installations. Anon. *Petrol. Engr*, Sept. 1950, **22** (10), B-11.—Presents methods of selection and the calculations involved in designing an entire sucker-rod pumping installation. Paper was compiled by the Mechanical Engineering Group of the Atlantic Refining Company. Tables and graphs permit comparatively simple determinations of suitable equipment. Certain assumptions involving present and ultimate oil, water, and gas-production pumping depths, fluid levels, and production rates are necessary before the design can be made.

Design begins with the sucker-rod pump, and it is necessary to choose a size of pump that will give the max desired production with the min load. The smallest size of pump that will handle the desired volume should be chosen. The optimum size of plunger may be determined by trial calculations to obtain corresponding beds and displacements for various size plungers under varying conditions. The type and sizes of sucker rods used will depend on the pumping loads and the nature of the fluid to be lifted. Selection of rods is facilitated by a series of tables giving limiting depths for various rod combinations with various plunger sizes for a range of pumping speeds. In selecting a pumping unit maximum load rating, peak torque rating, counter-balance necessary for max conditions, and length of stroke that can be obtained with the unit should be considered.

Peak load and peak torque are determined by Mill's formulæ, while counter-balance is best determined by use of instruments after installation.

Selection of prime movers and sheave sizes on prime movers and units are also dealt with. After units have been designed and installed, dynamometer studies should be carried out. These studies serve to check theory and to indicate changes in well

characteristics and conditions. The manner in which calculations, tables, and graphs are applied to the design and selection of equipment is illustrated by a detailed account of procedure.

An extensive bibliography is appended. C. G. W.

2648. Instruments for counter balancing pumping wells. L. W. Fagg. *Petrol. Engr*, July 1950, **22** (8), B-7.—It has been estimated that between 70 and 80% of all pumping wells are operating out of balance. Typical torque curves and dynamometer cards for unbalanced wells are shown. The use of a polished-rod dynamometer for estimating proper well counterbalance is outlined. An alternative to the polished-rod dynamometer is the recording tachometer. Using this instrument trial-and-error methods must be used.

References are appended. C. G. W.

2649. Electric power for oil well pumping on a lease subject to floods. T. E. Graham. *Petrol. Engr*, July 1950, **22** (8), B-52.—In an area subject to severe flooding, pumping equipment has been mounted above flood level. The prime movers used were electric motors controlled by an electric time clock. Records of power consumed indicate that the load factor has remained constant over a ten-year period in spite of long periods of flooding. C. G. W.

2650. Free pumping introduces new production practices. R. Sneddon. *Petrol. Engr*, July 1950, **22** (8), B-56.—Practices that are becoming routine in "free" pump installations are: checking of pump condition whenever production falls off; installing and frequently cleaning screens in the early stages of production, running pressure bombs to obtain a record of bottom-hole pressure at varying producing rates.

Other unusual practices made possible by the free pump are described. C. G. W.

2651. Selection and operation of pumping equipment. E. M. Fetzer. *Petrol. Engr*, July 1950, **22** (8), B-30.—Early designs of pumping units were influenced more by considerations of low first cost than by long-term performance. The necessity of good geometry in pumping structure is emphasized. Bad geometry causes severe and unnecessary forces, leading to early failure of surface equipment. It is also suggested that present specifications be extended to include deflections of members to predetermined tolerances.

Shock loads may be reduced by adjusting operating conditions, and critical frequencies should be avoided wherever possible. Engines with heavy flywheels may be operated with considerably less speed variation than those without. Large flywheels also lower the vibration frequency of the system, bringing the critical frequency outside the operation range. C. G. W.

2652. Hydraulic long stroke pumping units. W. F. Goertz. *Petrol. Engr*, July 1950, **22** (8), B-36.—Figures are given on the manufacture and application of hydraulic long-stroke pumping units, which are finding an important application in pumping wells deeper than 10,000 ft. At these very great depths sucker-rod failures are prevalent at the pumping speeds in use in shallow wells. Using the long-stroke (25 ft) hydraulic units, it is possible to get six times the displacement per unit time obtainable with a 74-in-stroke pumping jack.

With the long-stroke units the average life of sucker rods is greatly increased, an estimate of twenty-one years per break being given. This is particularly important in deep wells, where fishing jobs are difficult and expensive and where a pulling and reconditioning job causes a considerable downtime. Hydraulic units are also effective in shallow or medium-depth wells where large volumes are available. Five examples of actual field experience with these units are described. C. G. W.

2653. Reckoning well costs by well studies. K. M. Mills. *Petrol. Engr*, July 1950, **22** (8), B-13.—Reduced downtime due to a failure and wear of equipment is the major advantage of well studies. By maintaining a record of the frequency and location of equipment failures a study can be made, designed to determine the causes and remedies for such failures.

Failures may occur in the subsurface pump, the sucker rod or tubing string, or in the surface equipment. Dynamometer studies can indicate directly or indirectly, conditions likely to cause failure in any or all of these items. Pumping efficiency studies may be made by direct measurements. If a pump is operating at a low efficiency where a high fluid level exists in the annulus, one or more of the following conditions may be responsible: (1) pump pounding gas; (2) fluid leaking by valves; (3) fluid leaking by plunger; (4) fluid leaking in tubing.

The manner in which the polished-rod dynamometer can be manipulated to determine the presence of any of these conditions is described.

Pump failures due to corrosion may be avoided by using pump parts of alloys. Erosion by sand particles may be avoided to a certain extent by fitting a mud anchor. Damage to valves may be avoided by using double valves. Gas locking of pumps leading to "fluid pound" can be avoided by fitting gas anchors and oversize standing valves. In extreme cases changes in pump specification may be necessary. Sucker-rod failures are due to overstressing indicated by an excessive peak load in the pump cycle. When bent, nicked, and otherwise abused rods are eliminated causes of failures may be determined from the dynamometer card. Well conditions leading to excessive polished-rod loads are: (1) crooked hole, (2) excessive pump friction, (3) corkscrewed tubing, (4) paraffin in tubing on flow line. C. G. W.

2654. Use of explosives in oil and gas wells—1949 test results. B. F. Grant, W. I. Duvall, L. Obert, R. L. Rough, and T. C. Atchison. *U.S. Bur. Mines, Rep. Invest., No.* 4714, Aug. 1950.—Four series of experimental tests, made during 1949, to determine the most effective uses of explosives in shooting oil and gas wells, as measured in terms of production from the wells, are described. The records obtained with three types of strain gauges placed around the experimental shots permit determination of the generation and propagation characteristics of the strain wave are described. Water-injection tests made on the test holes before and after shooting allow the increase in fluid conductivity resulting from the shot to be determined. Two appendices cover a description of the physical property tests and the procedure for the determination of Young's modulus and Poisson's ratio under static-loading conditions. W. H. C.

Oilfield Development

2655. Probability, inferred and deduced, in petroleum prospecting. L. Wenger. *Bull. Ass. franç. Tech. Pétrole*, 1950, (83), 3–21.—Published statistics relating to successful wells and dry holes in various fields are reviewed from the standpoint of probability mathematics. Use of scientific (geological, geophysical) data has increased fourfold, as against wildcatting, probability of striking oil. Chances of a find, however, depend on richness of area as a whole, and is estimated as being, in France, only half that in the U.S.A. Results of French exploration programme are discussed and probabilities assessed; it is estimated that, in 1950, 15% of consumption will be met from domestic sources. V. B.

2656. Completions total record 24,422. Anon. *World Oil*, Sept. 1950, **131** (4), 52.—24,422 wells were completed in the U.S.A. during the first seven months of 1950, 10·5% more than in the same period of 1949.

A table shows well completions in the U.S.A. during July 1950 and cumulative for the year, by states or districts. C. A. F.

2657. Exploration for July at new high. Anon. *World Oil*, Sept. 1950, **131** (4), 102.—782 exploratory wells were completed in the U.S.A. in July 1950, compared with 757 in the previous month. 18·2% of the wells were productive. 113 new fields and 142 extensions to known fields were found.

10·7% more exploratory wells were completed in the first seven months of 1950 than in the same period of 1949.

Tables show the results of exploratory drilling in the U.S.A. in July 1950 and the first seven months, 1950–49, by districts; a survey of results of exploratory drilling; and the new oil, distillate, gas fields, and new pays discovered, by states. C. A. F.

2658. Kentucky drilled 460 oil producers in 1949. Anon. *Petrol. Engr*, Aug. 1950, **22** (9), B-72.—8,806,230 brl were produced in Kentucky in 1949, 118,061 brl less than in 1948. 1115 wells were drilled, of which 460 produced oil.

A deep test in Johnson County found gas at 5097–5100 ft and oil shows from 5365 to 5370 ft, but was abandoned.

In the Big Sandy gas field 186 wells were drilled in 1949, 149 of which produced gas.

In the White Creek field, in eastern Kentucky, twenty-seven wells were drilled.

C. A. F.

2659. New deep discoveries renew pre-Permian search in northwest sector. Anon. *World Oil*, Sept. 1950, **131** (4), 94.—The discovery in 1949 of the Bagley, Hightower, and Denton fields in Lea County, New Mexico, has renewed the search for pre-Permian production in the northeastern area of the Permian Basin.

The Bagley field, which produces from the Pennsylvanian and Siluro-Devonian, was discovered in July 1949. The neighbouring High-tower field, discovered in August 1949, found gas-condensate in Permo-Pennsylvanian in Jan. 1950. The Denton field, to the southeast, is producing from Devonian, Mississippian, and Permian Wolfcamp. All the structures are anticlinal and pay zones relatively thin. Wells are flowing

Drilling and completion practice is briefly described. C. A. F.

2660. Famed reef play greatly expanded by recent new discoveries. Anon. *World Oil*, Sept. 1950, **131** (4), 88.—In the last eighteen months, over 1000 wells have been completed in the new reef fields of West Texas. A large number of sites remain to be drilled.

The fields are on an arcuate line whose limbs trend northwards. Recently discovered fields in Terry and Kent counties have extended this northern trend.

Peak drilling activity has been passed in the Kelly–Snyder, Diamond M, and Sharon Ridge fields, where wells are being drilled on inside or edge locations.

The Cogdell area, discovered in December 1949, is being developed rapidly. Step-out wells indicate the area between Cogdell and Kelly–Snyder to be productive in the Canyon. There may also be substantial Cisco production at Cogdell.

Ten wells in the Salt Creek field in Kent County, discovered in April 1950, have proved an area 3 miles by 2 miles. There has been a marked increase in activity in several new areas southwest of the Scurry fields in southern Borden County.

Crude from the fields varies from 37° to 47°. Highest gravities are found in the Borden field. G.O.R. are generally less than 2000 : 1. Field development is on 40-acre spacing, and max base allowable is 160 b.d/well.

Drilling and completion practice are briefly described. C. A. F.

2661. Goldsmith 5600 pool outstanding for proved undrilled locations. Anon. *World Oil*, Sept. 1950, **131** (4), 98.—The Goldsmith field in West Texas has been an active producer since 1934. The field originally produced from the San Andres at about 4200 ft. Subsequently production was found in the Clear Fork (1946), Devonian (1947), Ellenburger (1947), and Upper Clear Fork (1947). There may be further development of pre-Permian production.

The Upper Clear Fork is being developed. Present proved productive area of this zone is 5½ by 10 miles. A large area remains to be drilled. Pay thickness varies from 110 to over 200 ft, and average total depth is 5800 ft. Initial well-production rate varies from several hundred to over 1500 b.d. of 38–39° oil. G.O.R. averages 600–800 : 1.

Completion practice is briefly described. C. A. F.

2662. Pegasus–Sweetie Peck fields demonstrate deep possibilities in Midland basin. Anon. *World Oil*, Sept. 1950, **131** (4), 96.—The Pegasus field was discovered in March 1949 and the Sweetie Peck field in March 1950. Both are in the Midland basin of West Texas.

Of the three wells drilled in the Sweetie Peck field, one produces from the Devonian, one from the Ellenburger, and one is a dual producer from the Wolfcamp and Pennsylvanian.

Productive limits of the fields are uncertain. At Sweetie Peck, development has been restricted to the immediate vicinity of the discovery well. Both fields are asymmetrical anticlines trending north–south.

Average depth of Ellenburger wells is 13,000 ft, with pay from 63 to 243 ft. Crude gravity is 52–53° and G.O.R. is 1200–1600 : 1 at Pegasus and 900–1000 : 1 at Sweetie Peck.

Casing programmes and drilling procedure are briefly discussed. C. A. F.

2663. Dollarhide field shallower Clear Fork now holds attention. Anon. *World Oil*, Sept. 1950, **131** (4), 100.—Production was found in the Clear Fork in the Dollarhide field in West Texas in 1949. Peak development of production from the Devonian, Silurian, and Ellenburger has been reached. The productive area of the shallower Clear Fork is expected to be greater than the deep zones. The Wichita–Albany zone, below the Clear Fork, may also be productive.

The structure of the Dollarhide field is a north-south-trending anticline. The Clear Fork is at 6285–6680 ft. Pay thicknesses are : Clear Fork, 300 ft or more ; Devonian, 30–115 ft ; Silurian, up to 200 ft ; and Ellenburger, 20–180 ft.

Most wells are flowing and are single or dual completed. Casing is generally set to bottom, and perforated. Most wells are acidized. C. A. F.

2664. The new reef fields of Texas. C. H. Keplinger and J. M. Wanenmacher. *World Oil*, Sept. 1950, **131** (4), 181.—The history and development of the reef fields in Texas are described. The reefs of Scurry, Kent, and Bordern counties form an arc, and it is believed that the recent Canyon discoveries in Terry County are a continuation of this trend.

The geology of the area consists of a thin Trias cover overlying Permian limestones, anhydrites, and shales, which reach 5500 ft. These overlie Pennsylvanian beds which are normally shales with minor sandstones and limestones, reaching 7900 ft. They are subdivided into the Strawn (lower), Canyon (middle), and Cisco (upper). The productive reef build-ups are first apparent in the Strawn, and the crest extends well into the Canyon. Structure does not appear to localize the reefs.

Oil–water level within the reef is not well defined, and is at approx 4500 ft subsea. The max pay thickness above water is over 700 ft at North Snyder. Average thickness is 200 ft. Porosity is variable, ranging from 2·23 to 14·4%. Permeability ranges from 0 to 100 mD.

The oil is undersaturated, with an average saturation pressure of approx 1750 p.s.i. Produced G.O.R. is about 850 : 1. Initial bottom-hole pressure in the North Snyder discovery well was 3112 p.s.i. at 4300 ft subsea, and current bottom-hole pressure varies from 2550 to 2980 p.s.i.

Development of the fields has been on 40-acre spacing. Production during May 1950 from the Cogdell, Diamond M, Kelly–Snyder, Reinecke, and Von Roeder fields was 2,358,214 brl, from a total of 845 wells. Total estimated recoverable oil in the Canyon reef, based on material balance, is 750 million brl.

Drilling and completion practice is briefly described. C. A. F.

2665. Petroleum-engineering study of the Carthage gas field, Panola County, Texas. C. J. Wilhelm, H. M. Harris, and M. N. Harlin. *U.S. Bur. Mines Rep. Invest., No.* 4698, Aug. 1950. -This study was made with the ultimate objective of assessing the gas reserves in the Carthage field. The topography and relief, drainage, general geology, and stratigraphy of the field are described, and descriptions are given of the Hill, Upper Pettit, and Lower Pettit reservoirs. Deep tests, drilling and completions, reservoir pressures, and temperatures are recorded and described. Calculated reserves of the reservoirs are shown. Cycling operations, processing plants, and out-turns are given. Gathering systems and pipeline capacities and extensions are described.

W. H. C.

2666. Saudi-Arabia production. Anon. *Petrol. Engr*, Aug. 1950, **22** (9), B-68.—Production in Saudi Arabia for June 1950 was 16,879,210 brl, or 562,640 b.d. Cumulative production for the year was 88,529,593 brl. C. A. F.

2667. Iran output up. Anon. *Petrol. Engr*, Aug. 1950, **22** (9), B-68.—Production in Iran for May 1950 was 2,771,000 long tons. Cumulative for the year was 13,053,000 long tons.

In 1949, 26,806,564 long tons were produced in Iran, and 45,419 long tons in the U.K. C. A. F.

Transport and Storage

2668. Quarter-century of pipe-line developments. Anon. *Oil Gas J.*, 21.10.50, **49** (20), 190.—The progress of pipelining from rough rule-of-thumb designs of 1925 to present-day practices is outlined. Modern systems are flexible, economical, function largely under automatic control, and cost less to install. Construction speeds are greater. G. A. C.

2668a. 11 Steps in pipe-line construction. Anon. *Oil Gas J.*, 21.9.50, **49** (20), 192.—Highlights of the complete undertaking of pipeline construction from start to finish are presented in eleven steps, including surveying, specifications, handling, crossings, welding, coating, backfilling, compressor stations, facilities, and service. G. A. C.

2669. Iraq–Mediterranean pipe lines—Part I. Anon. *Fluid Handling*, July 1950 (8), 218–24.—The existing 12-in pipelines of the Iraq Petroleum Co., from Kirkuk to Tripoli and to Haifa are being paralleled by 16-in lines, now nearing completion. The K section goes southwest from Kirkuk to Haditha on the Euphrates, where it divides into the T line westwards to Tripoli and the H line to Haifa via Transjordan and Palestine. The expansion requires greater pumping capacity, and the installation is described of the three pumping-stations on K line. Housing and all other needs of the crews are provided in this desert, and the methods employed of protection against the climate are described.

The 16-in lines were started in 1946. Ditching was carried out by drag shovels in Syria, but in Lebanon blasting was necessary. The welding was done by Murex and Lincoln and protected by primer, enamel, and fibreglass.

The generating plant for K stations is described in detail with diagrams. The centrifugal 156,000-b.d. pumps are driven by sixteen-cyl Crossley-Premier horizontally opposed diesels of 2000 h.p. through direct electrical transmission. The gradual starting technique is described. D. H.

2670. Iraq–Mediterranean pipe lines—Part II. Anon. *Fluid Handling*, Aug. 1950 (9), 252–7.—Mechanical features of the pumping equipment in the K, T, and H stations are given in detail, including pistons, frames, and crankshafts and their lubrication, valve mechanisms and materials of construction, air filtration, which is claimed 99·9% eff down to 5μ, and supply pipe insulation. D. H.

2671. Tapline pipe layers surmount problems in traversing mountains and desert. P. Reed. *Oil Gas J.*, 14.9.50, **49** (19), 109.—Techniques employed in laying the 1068 miles of 30- and 31-in crude oil system of the Trans-Arabian Pipe Line Co. in Saudi Arabia, Transjordan, Syria, and Lebanon are described.

The work was undertaken by two contractors, the first dealing with the 800-mile eastern section across deserts in Saudi Arabia, and the second with the 268-mile western section.

All pipe in the eastern section was laid with 90-ft joints, whereas that in the western division was laid with 30-ft joints in mountain areas and with 60-ft and 90-ft joints in less-rugged and rolling country respectively.

Pipes were laid in 54-in-deep ditches, giving 24-in cover, and was welded throughout.

A uniform thickness of glass fibre and saturated asbestos felt of $\frac{3}{16}$-in thickness was applied.

About 40% of the line is supported on short piers above ground in rocky country.

Tables list some of the major items of equipment used, and show main-line pump pressure and pipe sizing. G. A. C.

2672. Marine terminal of Trans-Arabian pipe line. P. Reed. *Oil Gas J.*, 21.9.50, **49** (20), 210.—The facilities for launching Tapline's submarine loading lines at the Sidon, Lebanon, terminal are described. The terminal has four offshore berths for loading crude oil into deep-sea tankers, with a combined maximum loading rate of 80,000 brl/hr. The submarine installation will consist of two 20- and two 30-in crude-oil loading lines.

Lines were pulled to offshore positions without the aid of a tanker; pontoons were used to buoy 20-in pipe, the 30-in pipe could float.

Pipes were sunk by admitting water, and " anchors " were made of concrete blocks.

G. A. C.

2673. Heating of petroleum products for pipeline transport. J. Pasqualini. *Bull. Ass. franç. Tech. Pétrole*, 1950 (82), 3–28; (83), 23–54.—Discussion given is stated to be based almost exclusively on Russian work. Ground covered includes thermal and hydraulic study of hot pipelines and examination of effect of cooling on flow conditions; consideration of Poiseuille's and Stokes's equations for non-isothermal laminary and turbulent flow and corrections to these equations; calculation of optimum pre-heat temp for products prior to their transfer by pipeline; expulsion of set products and re-heating when product has set solid; start-up operations in a hot pipeline; mutual interaction of heated underground pipelines when these are grouped; re-heating of lines. Numerous numerical examples are given, the formulæ used being based both on laboratory work and field trials. V. B.

2674. Equipment stresses imposed by piping. F. E. Wolosewick. *Refiner*, 1950, **29** (8), 89–91.—A discussion of the forces and moments experienced by pumps and turbines due to expansion of piping. Various types of supports and positions of expansion joints are considered. Suggested figures for max permissible forces on pumps and turbines are given, and emphasis is laid on the use of pre-straining to the extent of placing equipment under zero stress during operation. Complete pre-straining would increase safety, lengthen life of pumps and turbines, and reduce maintenance costs.

R. W. G.

2675. Hydromechanics research. Anon. *Mech. World*, 22.9.50, **12B** (3323), 272.—A technical session was included in the programme of the 1950 conference of the British Hydromechanics Research Association, and this was opened with an outline of the development of the theory of, and formulæ for, calculating energy losses in smooth straight pipes. While the friction in both smooth and uniformly rough pipes can be estimated reliably, there is much more uncertainty in case of commercial rough pipes which have very wide range of roughness size. Work of the association in this field has been to examine present formulæ to decide which are most reliable. The research on centrifugal pumps at Fouad I University, Giza, was then outlined, and this was followed by a discussion on cavitation and the research being carried out on this work at Mark Laboratories. It was shown that there are two distinct cases of cavitation attack on metals, and a description was given of the apparatus being constructed to investigate these points. Following this came a presentation of the graphical method of measuring pressure surges and the application of this to practical cases. Two examples of the application of the graphical method were discussed in detail. Finally, an outline was given of the way in which the association proposes to attack the existing problems connected with sealing devices. A. S.

2676. Grease plant and packaging centre. J. V. Hightower. *Chem. Engng*, 1950, **57** (4), 116–19.—The new plant at Richmond, belonging to Standard Oil Co. of California, incorporates many modern features in processing and handling equipment. White oils are bottled automatically at 15,000 pint or quart bottles in 8 hr. Drums and containers of all sizes are filled automatically by wt at 200 per hr and are moved by conveyors throughout the building, which is kept meticulously clean. Odours from greases and soaps are eliminated by a ventilating system, and an automatic graphite sprayer replaces the former manual method of coating sticks of grease. Aluminium stearate and other greases are heated by steam or Dowtherm in covered jacketed pans. Details are given of the electronically-controlled dispatching conveyor. D. H.

2677. Design and construction of a gas-compressor station. J. F. Eichelman. *Oil Gas J.*, 21.9.50, **49** (20), 203.—A step-by-step account of a compressor installation, from its inception until the completed plant goes into operation, based on installation of the El Paso Natural Gas Co., Texas, is given.

Selection of the compressor units, piping design and associated equipment, and electrical equipment are dealt with in three sections.

Selection of units depends on performance expected, and specifications should be laid down for the manufacturer of equipment.

Pressure piping is designed strictly to requirements of A.S.A. Code Section 3.

Associated equipment includes scrubbers, cooling equipment, water-pumps, and electric-power generators, transformers, switchgear, and control. G. A. C.

2678. A method for computing size of tanks at product pipe-line terminals. S. A. Hallberg. *Oil Gas J.*, 21.9.50, **49** (20), 214.—The Standard Oil Co., Ind., have provided a formula based on experience for a safe min-size tank to handle required terminal volume, which is flexible enough to provide tankage for any reasonable increase in terminal throughput without increasing the normal number of tenders of products pumped each month.

Examples are given. G. A. C.

2679. Underground storage and migration of natural gas. F. E. Vandaveer and J. J. Schmidt. *Oil Gas J.*, 27.7.50, **49** (12), 270.—The principal purposes of underground gas storage are in meeting peak loads and as a reserve in case of pipeline failure. Possible underground storage basins are: (1) depleted or partially depleted gas and oil fields; (2) excavations in sandstone, rock layers, or coal seams; (3) cavities in salt layers; (4) steel pipes or bottles buried underground.

The economics of underground storage and operations at present undertaken are briefly described.

Studies of gas migration have been made in a number of storage areas. Studies were based on specific gravities and heating values of gas produced, supplemented by rock-pressure data. Twenty references are appended. C. G. W.

2680. Practices and economics of block method of transporting several grades of products. W. C. Shannon. *Oil Gas J.*, 21.9.50, **49** (20), 284.—Methods used by Gulf Refining Co. for transporting several grades of oil, gasoline, or other products are outlined. Careful computation is essential of velocities of products in pipes, with estimates of arrival times at stated points.

Interfacial contamination of batches is greatest problem to be overcome. The water-spot method is not satisfactory; the rubber-swab method is useful. The modern tight-line method of operating a line under high pressure and at full capacity throughout its length, to minimize chances of interfacial mixtures, is good.

G. A. C.

Refinery Operations

Refineries and Auxiliary Refinery Plant

2681. Constructional work at Petrochemicals. Part I. H. E. Charlton. *Fluid Handling*, July 1950 (8) 229–34. (*From a paper presented to Manchester Ass. Engrs.*)—The plant, near the River Mersey and the village of Carrington, handles over 75,000 tons of naphtha p.a., which can be doubled with modifications. The naphtha is cracked to gases and liquids. Liquids are chemically treated and despatched as final products. The gases are fractionated at low temp and then synthesized into other chemical products.

The choice of site, civil-engineering problems, and structural steelwork are described, and special mention is made of the tower supports, which have no diagonal bracing, to facilitate fitting of auxiliary piping. D. H.

2682. Constructional work at Petrochemicals. Part II. H. E. Charlton. *Fluid Handling*, Aug. 1950 (9), 263–8.—Steam and certain other services are carried overhead on girders built up from three steel flats braced at 60° into 60-, 45-, and 30-ft standard spans. They are supported on biped tubular trestles, except at junctions and expansion joints, where a four-tube trestle is built. The thirty-three services are listed under headings: water, gases, drains, steam, liquids, electricity, and telecommunication. Plans of some of these are given. Economic surveys showed that oil fuel and cracked fuel gas was preferable to solid fuel for generating the steam at 600 p.s.i. and 400° C.

The refrigeration plant for gas separation is a cascade system using three refrigerants and one heat-transfer medium. Seventy-three heat exchangers of the cross-counter-current type were made with small-bore copper pipe wound on helically. Details of materials of construction and design codes are given. Instrumentation is 5–7% of total capital investment involving flow, ratio flow, level pressure, differential pressure, temperature, specific gravity, and pH. D. H.

2683. British refineries (No. 4) Scottish Oils Ltd., Grangemouth. Anon. *Petroleum*, Apr. 1949, **12** (4), 81–3.—Describes the important British refinery situated on the Firth of Forth, midway between Edinburgh and Glasgow, on the edge of the central Scottish industrial belt. Products at present include motor spirit, kerosine, tractor vaporizing oil, gas and fuel oils, and bottled butane. Details are given of a new expansion programme; refining capacity will be increased three-fold, and in addition an adjacent plant is being constructed for the manufacture of organic chemicals from petroleum. Plant will be owned and operated by British Petroleum Chemicals Ltd. R. E. P.

2684. New Shell Haven refinery. Anon. *Fluid Handling*, June 1950 (7), 185–91.—The cooling-water tunnel conveying water from the Thames is detailed in the overall description of the design and degree of completion of the refinery. There is a complete list of the main and sub-contractors for Shell Haven, and the costs of construction and expected throughputs of the new refinery are compared with those of Stanlow and Heysham. D. H.

2685. New Seeligson plant makes first use of centrifugals to compress raw gas. D. P. Thornton. *Petrol. Process.*, 1950, **5** (7), 714–18.—The installations are described at the new Seeligson field combination cycling and natural gasoline plant. It is capable of handling a total gas throughput of 220,000 M.c.f/day with an overall efficiency of 75% propane extraction yielding 500,000 gal per s.d. liquid products. Centrifugals are used for first-stage compression to supply gas at const pressure to the reciprocating compressors, giving flexible operation over a wide range with a claimed saving of $30–35/h.p. Several other unique features are mentioned. D. W. F.

2686. Refining developments in Holland. Anon. *Petroleum*, Feb. 1949, **12** (2), 34–6.—The article deals with the refining activities of the Shell Group in Holland. It describes recent extensions to the Pernis refinery and outlines future developments. Improved production of indigenous crude petroleum is also reported. It is stated that 27% of Holland's requirements of finished petroleum products is now supplied by oil from the field situated in the province of Drenthe. R. E. P.

2687. Sour gas—new plant operating MEA, dehydration, caustic and copper chloride units. M. H. Rahmes. *Refiner*, 1950, **29** (8), 118–22.—A description of a plant handling 50 M.c.f/day of sour gas, producing market propane, butane, and gasoline. R. W. G.

2688. Propane mixture purified, sweetened and dehydrated in one continuous operation. Anon. *Refiner*, 1950, **29** (8), 83–4.—A description of a plant producing 17·3 brl/hr of purified propane from mixed debutanized propane feed which contains traces of hydrogen sulphide and moisture. The feed is first fractionated in a 30-tray de-ethanizer, the ethane and methane passing overhead to the fuel-gas main. The propane bottoms are sweetened by caustic washing, passed through sand-filters to remove traces of caustic, and then dried over a bed of bauxite. The bauxite is regenerated by hot treated propane at 375° F, which is condensed to separate from the water. R. W. G.

2689. Three reasons why good housekeeping gets top rating in maintenance. Anon. *Petrol. Process.*, 1950, **5** (7), 720–1. (*From "Maintenance practices in a small refinery," by J. S. Pfarr, R. W. Pollard, L. T. Harris, and W. F. Dougherty, presented at the 15th Mtg A.P.I. Divn Refining, Cleveland, May* 3.).—Of the various phases of maintenance good housekeeping is considered to be of first importance at the Alma, Mich., 8500-b.d. refinery of Leonard Refineries. Reasons given for justifying housekeeping

costs were increased safety, improvements in operating conditions, and impression created on customers. Details of the programmes for shift operators and maintenance staff are described. D. W. F.

2690. Planning a large unit surround. E. E. McPherson. *Oil Gas J.*, 28.9.50, **49** (21), 94.—A 10-point programme devised by the Pure Oil Co., Ohio, to insure efficiency and economy in regular overhauling of refinery plant is described.

The inspection report of previous shutdown is studied, a definite date fixed for overhaul, and necessary materials for repairs ordered in good time. Maintenance operatives plan manpower distribution, and overhaul all maintenance tools in advance of date.

Close supervision and leadership is of importance to ensure completion to schedule. G. A. C.

2691. Flare tip gives long service life at low operating cost. W. S. Schellentrager and H. G. Briggs. *Petrol. Process.*, 1950, **5** (7), 736–8.—The most successful of the flare-tip designs developed at the Cleveland refinery of the Standard Oil Co., Ohio, is described in some detail. The most recent design consists of a 7½-ft length of 2-ft-dia tubing with a 6-ft-dia annular rim on the top to prevent back drafts forcing the flame down over the side of the stack. 50% of the primary air requirement is injected into the tip 2 ft below the rim by means of seven 6-in steam-inspirating-type gas burners, thus mixing the air and gas prior to ignition. A 1½-in protected pilot burner extends above the annular rim, and is supplied with high-pressure gas and air from a steam inspirator. Inconel was found to give the best service life, and was used throughout in the final design. The tip is rather complex, but has a low operating cost. D. W. F.

2692. Agitators. P. A. Helmbod. *Chim. et Ind.*, 1950, **64**, 147–59.—A review. The various aims of agitation are given and the energy requirements of different types of agitators operating in various vessels compared; variation in paddle design and vessel shape can cause energy consumption to vary as much as 50/1. Choice of agitators, drives, materials of construction for use with corrosive liquids are all considered, and a brief description is given of mixing by steam, compressed air, or pump circulation. 28 diagrams. V. B.

2693. Present-day pumping practice—Part I. N. Tetlow. *Fluid Handling*, June 1950 (7), 199–204.—Pumps are classified into direct-acting positive-displacement, variations of the direct-acting, rotary positive-displacement, and centrifugal pumps. The characteristics of each were considered on six relationships: discharge pressure and displacement (g.p.m.); g.p.m. and eff; g.p.m. and power; pump-inlet conditions and g.p.m.; starting torque and r.p.m.; and the variation of rate of flow over one cycle of the mechanism. The first three are conventional figures, but the fourth indicates the pressure drop required to make the fluid enter the pump, and tells whether it is likely to vaporize at the value and cause cavitation and vapour lock. The fifth influences the design of the power unit, and the sixth shows whether any smoothing device is required.

Methods of combating corrosion and difficulties in mechanical features are discussed, and many interesting examples illustrate the points. D. H.

2694. Present-day pumping practice—Part II. N. Tetlow. *Fluid Handling*, July 1950 (8), 225–8.—The problem of providing an adequate stuffing-box for each duty is dealt with extensively. Leakage of corrosive or non-lubricating liquids past the stuffing-box can be prevented by injecting an inert liquid or gas into the lantern ring at a higher pressure than inside the pump; by negative pressure vanes, which reduce the absolute pressure at the gland; or by mechanical seals for glandless pumps. Other solutions are offered by diaphragm pumps and air- or gas-displacement pumps, and complete submergence of pump and motor for work at around 5000 p.s.i.

Factors contributing to the correct design and type of pump for a specific problem, and its correct siting are discussed. D. H.

2695. Use of cascades at sharp elbows in water pipes. A. M. Binnie and D. P. Harris. *Engineer*, 1950, **190**, 232–5.—Introduction of cascade of thin turning vanes into sharp

elbow in 6-in dia water-pipe was shown to produce only slightly greater pressure drop than when standard 90° bend was used. Same elbow without cascade gave seven times greater pressure drop than with cascade. Considerable space-saving in pipe lay-out could therefore be made if required. A. C.

2696. Solid-fluid heat exchange in moving beds. W. D. Munro and N. R. Amundson. *Industr. Engng Chem.*, 1950, **42** (8), 1481–8.—A study is made of heat transfer and heat release in a fluid-moving solid exchanger in which the solid consists of uniform spheres. Conduction in the direction of flow is assumed negligible. Adiabatic conditions are assumed, thus limiting the applicability of the formulæ. For a reaction which does not generate heat, comparison may be made with previous approx treatments. Numerical cases are given which show that such methods may lead to considerable errors. Approximate methods are generally used when the time saved by their use is considerable. Graphical solutions have no advantage over the precise methods. Since it may be time-consuming as well as erroneous, the merits of each method must be considered for each particular case. R. G. T.

2697. Nomographs for orifice measurement of gas and liquid flow. J. Breuil. *Chim. et Ind.*, 1950, **64**, 300–9.—A series of eleven nomographs is given (with examples of calculations) enabling a solution to be obtained of the equation $Q = 1{\cdot}25d^2\alpha\varepsilon\sqrt{\frac{1}{\gamma}}\sqrt{n}$ for the range of Q of 10–10,000 m³/hr. Suitable for gas, water, and compressed air, but not for superheated steam. V. B.

2698. Alignment chart helps solve sweating problems. Anon. *Petrol. Process.*, 1950, **5** (7), 735.—A nomograph is presented, developed by the Industrial Mineral Wool Institute for determining min insulation thickness to prevent cold surfaces sweating. It is applicable to equipment enclosing low-temp fluids, and is based on an average value for the thermal conductivity of mineral-wool insulation. D. W. F.

2699. Entrainment separation by use of wire mesh. Anon. *Petrol. Process.*, 1950, **5** (7), 719.—Knitted wire-mesh pads are being used for entrainment separation in several operations. The large surface area and high free vol give high separation efficiency with a low pressure drop. D. W. F.

2700. Furnace fallacies. Anon. *Petrol. Process.*, 1950, **5** (7), 713.—Some factors concerning process-heater design and operation were revealed at the 1st Process Heat Seminar in Tulsa, June 10. Radiation from yellow or luminous flames may be 19–225% greater than from a clean blue flame. Lower H-to-C ratio fuels produce better radiating flames. A thermo-siphon effect due to cooling of gases by tubes causes considerable gas circulation within the furnace, furnace efficiency being raised if this circulation is encouraged by proper design. D. W. F.

2701. Gaskets and bolted joints. I. Roberts. *J. appl. Mech.*, 1950, **17**, 169–79.—A study is made of the loading requirements of gaskets in bolted joints with the object of developing a rational basis for the design of such joints. An analysis is given of gasket conditions for tightness and a gasket factor m is defined as $\frac{\sigma y^2}{p_i}$, where σy^2 is the average gasket stress at which a leak occurs when the internal pressure is increased to p_i. The variation of m with initial gasket stress and gasket width is predicted, and the general trends are confirmed by analysis of literature data. Bolted joints are considered, and equations are derived to predict gasket and bolt stresses resulting from internal fluid pressure. Typical elastic-recovery curves for an asbestos gasket are presented. Gasket creep in a bolted joint is considered, and an approx theory is derived for the distribution of bolt load. Defects in the ASME code are pointed out, and a new design procedure is proposed. A summary of data which are needed for the new procedure is given. D. F. J.

2702. Solved—difficult waste disposal problem. K. M. Brown and S. Kuntis. *Refiner*, 1950, **29** (8), 111–15. (*Western Petroleum Refiners Ass. Mtng,—Wichita, Kansas,*

June 1950.)—Description of a process using flue gas suitable for neutralizing refinery spent caustic prior to disposal. Refinery spent caustic contains some of the most objectionable materials to aquatic life—such as sulphides, mercaptides, phenolates, and thiophenolates. These may be displaced by CO_2, which also neutralizes the caustic. Post-war catalytic-cracking units make available flue gas under pressure (15–20 p.s.i.g.) and this overcomes difficulties in compression due to corrosion. Two batch units are described. R. W. G.

2703. The role of the process engineer in the petroleum refinery. C. C. Wuth. *I.P. Review*, 1950, **4**, 284.—There is no definite course of study or training for the position of process engineer, but the duties of a person who fills such a position are manifold. He is essentially concerned with process design and operation. The process engineer must have certain qualities—he must be a practical man, be instrument-minded, be a realist, be a master of compromise, and must be aware of the limits imposed on practice by economic considerations. The job is generally filled by a mechanical or chemical engineer. The process engineer is responsible for: (1) process flow (process flow diagrams are described in detail); (2) plant revamping (when process changes take place); (3) heat balancing (very important from the economic standpoint); (4) fluid flow (involves transfer of liquids and gases between various operating systems); (5) instrumentation (probably the most important—it involves measurement and control of process variables).

In the refinery the process engineer can be trained only by practical experience. R. H.

Distillation

2704. Bubble trays—designs and layout. Part I. J. A. Davies. *Refiner*, 1950, **29** (8), 93–8.—A detailed discussion of the mechanical features involved in the design of distillation bubble-cap trays. The features involved in tray design are presented in an organized manner, enabling engineers without considerable experience to select suitable tray constructions and materials. R. W. G.

2705. Flexible clay-treating and vacuum distillation unit. Anon. *Oil Gas J.*, 14.9.50, **49** (19), 102.—The modernized combination clay-treating and vacuum-distillation unit at Oleum, Calif., refinery of Union Oil Co. is described.

In addition to handling the Triton motor oils, the plant will treat various other products by operations such as Filtrol fractionation of dewaxed Duo-Sol raffinates and of turbine oils.

The vacuum column is 13 ft 6 in in dia, contains twelve fractionating trays in main section and three stripper trays in base, and takes a charge of 2700 b.d.

The unit can also be operated as a straight vacuum distillation unit without using any of the clay facilities. G. A. C.

2706. Material transfer and friction losses in packed columns for distillation and absorption. F. J. Zuiderweg. *Ingenieur*, 20.10.50, **62**, (42), 75.—Subject dealt with in eight sections. The analogies of a number of workers in this field, including Reynolds, Prandtl-Taylor, Chilton-Colburn, von Karman, and Sherwood, are briefly referred to. In cases of ideal gas and liquid distribution, the coeff of material transfer calc from the pressure drop are in fairly good agreement with the values found experimentally. For gas absorption or dist processes carried out in columns with the customary packing units however, the transfer coeff predicted from the pressure drop are many times greater than those found experimentally. It may be concluded that operation of these columns is relatively inefficient in consequence, probably of poor liq distribution. R. R.

2707. Factors controlling efficiency and capacity of sieve-plate extraction towers. C. Pyle, A. P. Colburn, and H. R. Duffey. *Industr. and Engng Chem.*, 1950, **42** (6), 1042–7.—In this study the system ethyl ether–acetic acid–water was used with an 8½-in dia glass column, 38½ in tall containing four plates 4½ in apart. Five interchangeable sets of plates were used covering different hole sizes and percentage of hole area. Plate efficiency on ether film basis was found to be about 0·3, this being increased slightly for high percentage free hole areas, for smaller holes, and for increasing plate

spacing. For large-dia towers the authors state that a spacing of 7–8 in would probably be desirable. Plate efficiency was found to decrease as the ratio of ether to acid solution was increased, a feed acid conc of about 25% gave better efficiencies than 0·5% acid. Normally the phase with the greater vol flow rate (in these tests ether) should be dispersed. Capacity may be limited by the required pressure drop across the plates or by the time for separation of emulsions. Seven references. D. W. F.

2708. Dehydration of ethyl alcohol by fractional extraction. E. G. Scheibel. *Industr. Engng Chem.*, 1950, **42** (8), 1497–508. (*Divn Industr. Engng Chem.*, 116*th Mtng, Amer. Chem. Soc., Atlantic City, N.J.*)—The dehydration of ethyl alcohol by fraction liquid extraction is described. A high-boiling ketone and glycol and a high-boiling aromatic hydrocarbon and glycol are used—methods of estimating distribution coeffs, from published equilibrium data and the application of the data to the column calc, are described. The aromatic–glycol mixture is used if anhydrous alcohol with 2% aromatic is required. Absolute alcohol is produced by the ketone–glycol mixture at a slightly higher cost, but still much cheaper than by previous methods. Performance characteristics of a multistage liquid-extraction column were investigated. Stage eff increased with the height of packing between mixing sections to 100% and over. The packing height required for the high efficiencies was found to be greater than with previous solvent pairs. A complete process design is prepared for alcohol dehydration with each pair of solvents. R. G. T.

Absorption and Adsorption

2709. Sholem Alechem gasoline plant processing 30 million cu. ft. per day. R. F. Carlson. *Oil Gas J.*, 7.9.50, **49** (18), 60.—This plant operated by Magnolia Petroleum Co. in Stevens County, Oklahoma, is designed to take field gas from well-head separators at about atm pressure. Compressors raise pressure to 800 p.s.i., and conventional methods process 30,000,000 cu. ft. gas/day, which can be increased to 50,000,000 cu. ft. by installation of additional compressor units.

Plant was designed to recover 64% of propanes, 98% of butanes, and essentially 100% of gasoline content. G. A. C.

2710. "Packaged" gasoline plant. R. B. Tuttle. *Oil Gas J.*, 7.9.50, **49** (18), 78.—A plant has been designed by Portable Gasoline Plants, Tulsa, to process small volumes of wet gas (500–4000 M.c.f. daily) which can be erected in three days as a field processing unit.

Unit requires only 1 hr routine inspection daily when operating, as plant is fully automatic.

Heat for operation is generated within the plant.

A description of a unit which has processed an average of 700,000 M.c.f. gas/day for two months without continuous attention of an operator is given. G. A. C.

Solvent Extraction and Dewaxing

2711. Liquid–liquid extraction correlation of H.T.U. with interfacial tension. J. C. Chu, C. C. Taylor, and D. J. Levy. *Industr. Engng Chem.*, 1950, **42** (6), 1157–63.—The effect was studied of several surface-active agents on the efficency of liquid–liquid extraction in a 6·5 ft × 2 in inside dia glass column packed with ½-in Raschig rings. Benzoic acid was extracted from benzene, also containing a small amount of the surface-active agent, by means of a dispersed-water phase. For the highly active agents interfacial tension was greatly reduced, resulting in smaller drops and a higher efficiency of extraction, H.T.U. decreasing linearly with decrease in interfacial tension of the system. At higher concentrations of the surface-active agent the diffusional resistance offered by the orientated molecules at the interface more than counterbalances the increase in interfacial area. D. W. F.

2712. Mass transfer coefficients in an extraction spray tower. C. J. Geankoplis and A. N. Hixson. *Industr. Engng Chem.*, 1950, **42** (6), 1141–51.—Mass-transfer coefficients in a liquid–liquid extraction spray tower 1·45 in dia, 2·57 ft long have been studied

using the system *iso*propyl ether–$FeCl_3$–aq HCl. Internal operation of the tower was investigated by the use of a travelling sampling tube to remove samples of the continuous aqueous phase. Conc gradients and transfer coefficients at any pt in the column could be determined and so mass-transfer end effects evaluated. The comparatively large end effects noticed were not affected by inlet design or interface surface area at column head. Fifteen references. D. W. F.

Cracking

2713. Prefabricated catalytic cracking units now available in "packaged" form. W. F. Bland. *Petrol. Process.*, 1950, **5** (7), 711–12.—T.C.C. units of 3000 b.d. and 6000 b.d. nominal capacity are now available in completely prefabricated form. Engineering design of the cracking section is handled by Socony Vacuum Oil Co., the remainder of the plant including feed preparation and stabilization by South Western Engineering Co. of Los Angeles. A standard oilfield derrick is the support for the catalyst hopper, reactor, and regenerator, and also serves as a construction rig during erection. A catalyst air lift replaces the original bucket elevators. Total cost for the smaller unit given as approx $200–250/brl. D. W. F.

2714. New catalytic cracking process. Anon. *Petroleum*, Mar. 1949, **12** (3), 66–7.—An improved moving-bed catalytic-cracking process developed by Houdry Process Corpn is described. The process, named Houdriflow, retains many features of the T.C.C. process, but differs from it in four major respects.

1. A flue-gas lift transports pelleted or bead catalyst from the bottom to the top of the unit, replacing the bucket-type elevator.
2. Catalyst-to-oil ratios in the range of 4–8 instead of 2–3.
3. A simplified regenerator made possible by high catalyst circulation rates, one or two burning zones are sufficient.
4. A superimposed, self-supporting, circular reactor and regenerator section, therefore smaller ground area and only necessary to lift catalyst once.

It is stated that initial capital investment for a Houdriflow unit is approximately 80% that of a conventional T.C.C. unit of the same capacity. Direct operating and maintenance cost will also be materially reduced. R. E. P.

2715. Catalytic cracking, Part II. M. Sittig. *Refiner*, 1950, **29** (8), 99–104.—A detailed description of the operation and mechanical features of the Thermofor catalytic-cracking process. Advantages of synthetic catalysts over pelleted clay and methods of catalyst transportation are discussed. Reference is made to the Houdriflow catalytic-cracking process, which retains the essential features of the Thermofor process, but has the reaction chamber placed directly over the catalyst regeneration kiln and uses flue-gas lifting for the catalyst in place of bucket elevators. The important features of this process are low construction and operating costs. A good bibliography on the operation and mechanical design is presented. R. W. G.

Hydrogenation

2716. Catalytic hydrogenation of carbon dioxide to higher hydrocarbons. W. W. Russel and G. H. Miller. *J. Amer. chem. Soc.*, 1950, **72**, 2446–54.—Different types of copper-activated cobalt catalysts have been used in studying the catalytic hydrogenation of carbon dioxide to higher hydrocarbons at atmospheric pressure and at temp ranging from 175° to 300° C. Catalysts free from alkali produced no liquid hydrocarbons or only traces, but after being poisoned did yield small quantities of liquid product. When the catalyst was alkalized with potassium carbonate or phosphate it was possible to obtain liquid hydrocarbons. It appears that the alkali acts as a selective poison for methane-forming centres.

The synthesis life and catalyst activity can be increased by the addition of cerium oxide to the alkalized catalyst. When such a cerium-oxide-alkalized catalyst is supported on natural kieselguhr, methane is the only synthesis product, but when a flux-calcined kieselguhr is used as a support the synthesis product contained nearly as much liquid hydrocarbons as an unsupported catalyst of similar composition.

The optimum synthesis temp was found to be in the region of 225° C, but was dependent on catalyst activity and composition. When synthesis temp were increased by 25°–100° C a selective poisoning was obtained, which resulted in an increased yield of liquid products when the synthesis was resumed at the initial temp.

The max yield of liquid product was 95 ml/cu. m. of carbon dioxide used together with 360 litres of gaseous hydrocarbons. W. H. A.

2717. Liquid fuel from coal—first year of operation of coal hydrogenation demonstration plant at Louisiana, Mo. L. L. Hirst and C. C. Chaffee. *Industr. Engng Chem.*, 1950, **42**, 1607.—Five runs have been made during the first year of operation of the hydrogenation demonstration plant at Louisiana, Mo. (see Abs. No. 1164, 1949.) Improvements during the year are described. Temp measurement, liquid-level gauges (γ-ray instrument), and diaphragm-actuated values are discussed. A four-cell coal-paste preheater, of the radiant type, has given satisfactory performance. Stannous oxalate cat is to be replaced by iron. R. G. T.

2718. High-pressure hydrogenation of carbonaceous matter. Part VIII. P. W. Sherwood. *Refiner*, 1950, **29** (8), 107–10.—This last article of the series discusses the overall requirements and performance of high-pressure hydrogenation as applied to various raw materials. Economic and thermal efficiencies are considered, and comparison is made with the Fischer–Tropsch process. Cost figures, based on German plant, are given. R. W. G.

Polymerization

2719. Studies in plasticization of polyvinyl chloride. I. Physical changes and their measurement. M. L. Dannis. *J. appl. Phys.*, 1950, **21**, 505–9.—The softening of a hard resin such as polyvinyl chloride by a plasticizer, dioctyl phthalate, or *m*-tricresyl phosphate occurs as a set of sequential processes. Imbibition of the liquid brings about a reduction in volume in the system, the rate and amount of which can be measured by dilatometer methods. The rate is temp dependent and has an activation energy of 80 k.cal. The change in dielectric constant is not uniform, and appears to follow the exponential decay of source material into products, which has an activation energy of 110 k.cal. The shrinkage data cannot be expressed by the same relationships that "linearize" the dielectric data. N. T.

2720. Studies in plasticization of polyvinyl chloride. II. Plasticizer variations in PVC plasticizer systems. M. L. Dannis. *J. appl. Phys.*, 1950, **21**, 510–13.—Plasticization of polyvinyl chloride takes place through a series of processes having activation energies from 50 to 100 k.cal. For fixed temps the "reaction" rates are directly proportional to the vapour pressure of the plasticizer. The treatment of dielectric changes as a chemical reaction between a solid and a vapour shows that the free energy of activation is constant for various liquids with one resin. The Arrhenius activation energy of the dielectric-rate plot differs from the heat of activation by the latent heat of vaporization of the plasticizer used. N. T.

Special Processes

2721. X-Ray diffraction studies of the action of carbon monoxide on cobalt–thoria–kieselguhr catalysts. II. L. J. E. Hofer, W. C. Peebles, and E. H. Bean. *J. Amer. chem. Soc.*, 1950, **72**, 2698–701.—At temp below 235° ± 10° C carbon monoxide reacts with finely divided cobalt forming only cobalt carbide, above this temp inert free carbon is also formed. The formation of such carbon on Fischer–Tropsch synthesis catalysts results in mechanical disintegration of the catalyst and in a change of product distribution towards lighter hydrocarbons, particularly methane. These effects are distinct from the inhibiting effect of cobalt carbide on the synthesis.

By X-ray-diffraction studies information has been obtained about the reactions occurring above the critical temp of 235° C. Using a reduced cobalt–thoria–kieselguhr catalyst, it was found that increasing amounts of free carbon and decreasing amounts of cobalt carbide were formed on carburizing with carbon monoxide at increasing

temperatures in the range 243°–298° C. The max amount of carbide is formed during the first 5 hr of carburization at the high temp.

That the presence of free carbon tends to make further carbide formation impossible was shown by reducing a high-temp carburized catalyst with hydrogen and recarburizing at 220° C, when it was found that the amount of carbide reintroduced was roughly equal to that removed by hydrogenation. The results obtained on carburizing a fully carbided catalyst at 285° C showed that the presence of carbide inhibits free carbon deposition. W. H. A.

Metering and Control

2722. The console graphic panel. W. S. Bowers. *Petrol. Process.*, 1950, **5** (7), 722–5.—The graphic panel method of instrumentation is analysed with regard to its many advantages over the normal control panels, together with a description of the U-type console panel of the recently installed solvent refining and dewaxing lube oil plant at the Lima, Ohio, refinery of Standard Oil Co. A cost comparison reveals that an overall saving of 15% is achieved. Items mentioned are ease of assessment of process, ease of control from the panel, inclusion of indicators normally situated on the plant, and economy in space. D. W. F.

2723. The measurement and control of temperature. W. A. Goldstein. *Petroleum*, Mar. 1949, **12** (3), 55–60.—The following physical properties vary with temp, and all are used in its measurement: dimensions, vapour pressure, electrical resistivity, thermo-electric e.m.f., colour, total surface radiation, and physical state. Instruments depending on such physical changes are described, the article covering the general principles of operation of the various types of equipment available, the useful range and accuracy of each, and other relevant details.

Significant points are given in the choice of equipment and for correct installation to obtain the inherent accuracy of the equipment. Author also outlines the broad principles of automatic temp control and describes some systems. R. E. P.

2724. Comparative tests on commercial CO_2 recorders. L. J. Flaws and W. Hill. *J. Inst. Fuel*, Sept. 1950, **23** (133), 236.—Tests are described on the following types of commercial CO_2 recorders: chemical-absorption, diffusion, thermal-conductivity, and density. Six representative recorders were obtained, and were mounted side by side on a suitable framework. They were kept in continuous operation on gas drawn from the flue of a hand-fired Lancashire boiler over a period of six months. Instruments were operated and adjusted as far as possible on makers' instructions, and during the tests the instruments were given no more skilled attention than could be made available in most small works. Servicing time, gross and net, variation in zero reading, time-lag, and accuracy are aspects considered. Under conditions described the thermal-conductivity type proved to be the most accurate and sensitive, but the density type also gave good response. Numerous graphs are included. D. K.

2725. Maintenance and repair of refinery control valves. W. H. Fortney and C. C. Pryor. *Refiner*, 1950, **29** (8), 77–82.—A detailed description of a routine procedure for installing, maintaining, and repairing control valves on units. Emphasis is laid on the importance of regular checking of valves, and of details of performance and repairs being kept by valve repair shop. R. W. G.

2726. Meter maintenance. J. J. Harris. *Oil Gas J.*, 21.9.50, **49** (20), 334.—Magnolia Pipe Line Co. have found that performance of meters depends largely on correct operation and preventive-maintenance programme. Cost of maintenance averages 0·003–0·004 cents/brl throughput.

Meters should be periodically inspected and cleaned, and where possible all meters frequently run. G. A. C.

2727. Nomograph for orifice calculations. T. H. Arnold, Jr. *Refiner*, 1950, **29** (8), 123–5.—Nomographs are presented for use in selecting design details of sharp-edged orifices for metering flow in given pipelines. R. W. G.

PRODUCTS

Chemistry and Physics

2728. Action of bromine vapour on solid aromatic compounds. R. E. Buckles, E. A. Hausman, and N. G. Wheeler. *J. Amer. chem. Soc.*, 1950, **72**, 2494–6.—Twenty solid aromatic compounds reacted with bromine vapour to yield products in which the *p*-position of unsubstituted phenyl groups were brominated and in which olefinic double bonds not highly substituted added bromine. The reaction was carried out in a dessicator containing an open vessel of liquid bromine in the lower part and the finely powdered solid compound in a dish on a rack above the bromine. The lid of the dessicator was not completely closed, since considerable volumes of hydrobromic acid are sometimes evolved.

It is considered that reaction with bromine takes place in an adsorbed phase on the crystal surface, in a film of a solution of the aromatic compound in liquid bromine or in a combination of both. An ionic mechanism is postulated in which the double bond, the aryl system or their combination exhibit basic characters and form a complex with the bromine of the type $ABr^{+}Br^{-}$; in the case of highly arylated double-bond systems more than one halogen molecule can be involved in the association. Such an intermediate could stabilize itself by addition of bromide ion to give olefin dibromide, by elimination of hydrogen bromide to yield a brominated product, or by reverting to the original aryl compound with evolution of bromine. W. H. A.

2729. Low temperature autoxidation of hydrocarbons : The phenomenon of maximum rates. A. V. Tobolsky, D. J. Metz, and R. B. Mesrobian. *J. Amer. chem. Soc.*, 1950, **72**, 1942–52.—Bolland and Gee's mechanism of autoxidation is discussed, and from a mathematical extension it was possible to predict the occurrence of steady states of hydroperoxide concentration and steady rates of oxygen absorption.

When autoxidation activators such as heavy metal ions or light are used, they accelerate the initial phases of autoxidation by hastening the decomposition of hydroperoxides, but they have no effect on the max rate of autoxidation, which is a function of temp only. Experimental confirmation was obtained from a study of the max rates of oxidation of vulcanized rubber in which light acts as an activator at low temp, but when the temp is sufficiently high it has no effect.

From stress-relaxation measurements it was found possible to calculate the number of chain cleavages and the number of molecules of oxygen per scission. It was found that the number of oxygen molecules absorbed per chain cleavage was large at low temp, but under conditions of max rate of oxidation the number of oxygen molecules absorbed per chain cleavage is approximately unity. W. H. A.

2730. 2 : 3-Dithiobutane : Low temperature heat capacity, heat of fusion, heat of vaporization, vapour pressure, entropy and thermodynamic functions. D. W. Scott, H. L. Finke, M. E. Gross, G. B. Guthrie, and H. M. Huffman. *J. Amer. chem. Soc.*, 1950, **72**, 2424–30.—2 : 3-dithiobutane as the simplest member of the alkyl disulphides was chosen for the initial study of this class of organic sulphur compounds to determine the effect of structure on thermodynamic properties. The necessary low-temp thermal measurements were made using an apparatus similar to that of Ruehrwein and Huffman, and the methods of Waddingron *et al* were used for vapour-pressure determinations. The heat capacities and vapour pressures so determined enabled the heat of vaporization and entropy to be calculated. Previously published spectroscopic and electron diffraction data were used in obtaining a value for the free energy function, heat content, entropy, and heat capacity. W. H. A.

2731. Isomerization accompanying alkylation. V. Reaction of 4-methyl*cyclo*hexene with benzene in the presence of hydrogen fluoride. V. N. Ipatieff, E. E. Meisinger, and H. Pines. *J. Amer. chem. Soc.*, 1950, **72**, 2772–4.—Previous papers in this series reported the shifting of the double bond which often accompanies the reaction of open-chain olefins with benzene. In the reaction between isomeric methyl*cyclo*hexenes including pure 4-methyl*cyclo*hexene and benzene in the presence of hydrogen fluoride at 0·5° C the same product was formed in each case. Examination of this product indicates that it is most likely 1-methyl-1-phenyl*cyclo*hexane. W. H. A.

2732. Cyclic polyolefins. V. Preparation of bromo*cyclo*-octadienes and 1 : 3 : 5-*cyclo*-octatriene from 1 : 5-*cyclo*-octadiene. A. C. Cope, C. L. Stevens, and F. A. Hochstein. *J. Amer. chem. Soc.*, 1950, **72**, 2510–14.—Two isomeric monobromo*cyclo*-octadienes were isolated from the reaction product of 1 : 5-*cyclo*-octadiene with N-bromosuccinimide. These compounds were interconvertible and appear to be allylic isomers. Reaction of the isomer mixture with potassium *t*-butoxide yielded 1 : 3 : 5-*cyclo*-octatriene, which was also obtained by treating 5 : 8-dibromo-1 : 3-*cyclo*-octadiene with magnesium. This dibromo derivative was also prepared from 1 : 5-*cyclo*-octadiene and N-bromosuccinimide by increasing the proportion of the latter to two equivalents as compared with less than one equivalent used in preparing the monobromo*cyclo*-octadienes. W. H. A.

2733. Cyclic polyolefins. VI. Preparation of *cyclo*-octatrienes from *cyclo*-octatetraene. A. C. Cope and F. A. Hochstein. *J. Amer. chem. Soc.*, 1950, **72**, 2515–20.—*Cyclo*-octatetraene reacts with 2 mol of sodium in liquid ammonia to yield an orange-coloured sodium derivative which when treated with ammonium chloride decomposes, forming a mixture of 1 : 3 : 5-*cyclo*-octatriene and 1 : 3 : 6-*cyclo*-octatriene. From this mixture the 1 : 3 : 6-isomer may be separated in 94–96% purity by fractional distillation. Treatment of the mixture of isomers with potassium *t*-butoxide results in the re-arrangement of the unconjugated to the conjugated isomer, thereby providing a convenient method for the synthesis of 1 : 3 : 5-*cyclo*-octatriene.

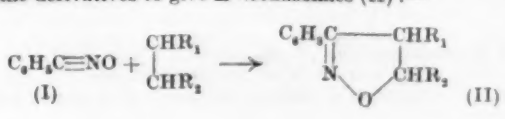
When heated the 1 : 3 : 5-isomer re-arranges, forming a compound with lower refractive index and an almost identical ultra-violet-absorption spectrum which is not the 1 : 3 : 6-*cyclo*-octatriene, but is considered to be either a stereoisomer or a bridged-structure isomer.

Cyclo-octatetraene gave three crystalline addition products with silver nitrate, and 1 : 3 : 5-*cyclo*-octatriene also yielded a crystalline adduct with silver nitrate. These addition compounds have proved useful as derivatives and for purification of the hydrocarbons, which can be regenerated from them by decomposition with aqueous sodium chloride followed by steam distillation. W. H. A.

2734. Free radical-initiated reaction of ethylene with halomethanes. J. Harmon, T. A. Ford, W. E. Hanford, and R. M. Joyce. *J. Amer. chem. Soc.*, 1950, **72**, 2213–16.—The reaction was carried out by heating the halomethane with water and a small quantity of benzoyl peroxide under an atm of ethylene at pressures ranging from 100 to 900 atm. The product was separated into its components by fractional distillation. Different halomethanes were employed, and in each case the individuals obtained could be expressed by the general formula $x(CH_2{\cdot}CH_2)_n y$, where x is hydrogen or halogen and y the remainder of the halomethane molecule; n varies inversely with the reactivity of the halomethane, which diminishes as the number of halogen atoms in the molecule decreases. The relative reactivity of the halogens is in the order I > Br > Cl. W. H. A.

2735. Synthesis of parathion and some closely related compounds. J. H. Fletcher, J. C. Hamilton, I. Hechenbleikner, E. I. Hoegberg, B. J. Sertl, and J. T. Cassady. *J. Amer. chem. Soc.*, 1950, **72**, 2461–4.—A new method for the synthesis of parathion is described. O,O-diethyldithiophosphoric acid is prepared by refluxing phosphorus pentasulphide suspended in an inert solvent with ethyl alcohol. Chlorination of the reaction product yields the corresponding monochlorothiophosphoric acid, which after separation is refluxed with sodium *p*-nitrophenate in acetone to give parathion in good yield and of high purity (< 95%). The method was applied to the synthesis of six *O*-*p*-nitrophenyl thiophosphate esters not previously characterized. W. H. A.

2736. New reaction of ethylenic double bonds. A. Quilico, G. S. D'Alcontres, and P. Grünanger. *Nature*, 1950, **166**, 226.—Benzonitrile oxide (I) in ethereal solution reacts easily with ethylenic derivatives to give **Δ^2-*isoxazolines*** (II) :—



The olefinic compounds tested include: allyl and vinyl compounds, methyl acrylate, mallate, citraconate, and mesaconate; maleic anhydride, styrene, stilbene, indene, and bicyclopentadiene.

It is suggested that the reaction can be used for the identification of unsaturated liquid substances. H. C. E.

2737. Vapour pressures of normal saturated hydrocarbons. G. Thodos. *Industr. Engng Chem.*, 1950, **42** (8), 1514–26.—A study of vapour pressures between the triple and crit points of the normal saturated hydrocarbons up to *n*-dodecane has been made after a critical literature survey of experimental v.p. data. Accurate correlation of the data is possible only if high and low v.p. regions are treated separately. V.p. data in the low v.p. region is expressed by the general equation

$$\log P = A + B\left(\frac{1}{T}\right) + C\left(\frac{1}{T}\right)^2.$$

A graphical residual—$D\left(\frac{T}{T_D} - 1\right)^n$—must be introduced to cover the high v.p. region. The constants A,B,C,D, and n were determined for each hydrocarbon and are related to the normal b.p. Average absolute error in many calculations of v.p. is 0·5%, showing marked improvement over previous correlations. Extensive bibliography is appended. R. G. T.

2738. Thermal conductivity of gas mixtures. A. L. Lindsay and L. A. Bromley. *Industr. Engng Chem.*, 1950, **42** (8), 1508–11.—Equations are developed for the calculation of thermal conductivities, and have been used to calculate conductivity of twenty-five compositions of sixteen gas pairs for which published data are available. Average deviation from experimental determinations is 1·9%. The equations are based on knowledge of thermal conductivity, heat capacity, visc, normal b.p., and mol. wt. of the pure gases. R. G. T.

2739. Charts solve polytropic P-V-T relations for perfect gases. W. T. Rice. *Chem. Engng*, 1950, **57** (4), 120–2.—The basic equations for expansion and compression of ideal gases are solved by three graphs. Given the ratio of compression and actual discharge temp, polytropic exponent n, and the polytropic and adiabatic efficiencies e_p and e_a of the process are readily calculated.

Four numerical examples are given. D. H.

2740. Water gas shift reaction—effect of pressure on rate over an iron oxide–chromium oxide catalyst. K. Attwood, M. R. Arnold, and E. G. Appel. *Industr. Engng Chem.*, 1950, **42**, 1600–2. (*Divn Gas & Fuel Chem., 116th Mtng, Amer. Chem. Soc., Atlantic City, N.J.*)—The influence of pressure on the rate of the water-gas shift reaction over a commercial iron oxide–chromium oxide cat, was studied in the pressure range of 1–30 atm at 655° and 760° F. The activity of the cat approx doubled as the pressure was raised to 10 atm, and increased only slightly as the pressure was raised further. Plots of cat activity *vs* pressure, give curves that are similar in shape to Langmuir isotherms. (Author's Abstract.) R. G. T.

2741. Drop formation in two-liquid-phase systems. C. B. Hayworth and R. E. Treybal. *Industr. Engng Chem.*, 1950, **42** (6), 1174–81.—Drop formation from a single nozzle, in the dispersion of one liquid into a stationary immiscible liquid, was studied as a function of certain physical properties and flow conditions of the system. These variables are nozzle dia, velocity through nozzle, interfacial tension, density, and viscosity of both liquids. Drop size was found to be uniform up to 10 cm/sec, to decrease and be less uniform from 10 to 30 cm/sec, and to be erratic at >30 cm/sec. A semi-empirical equation has been developed permitting prediction of drop size within 7½% in the range 0 to 30 cm/sec nozzle throughout. Twenty-one references. D. W. F.

2742. Principles of emulsification. A. H. Stuart. *Paint Mnfr*, Oct. 1950, **20** (10), 353.—The miscibility of oil and water to produce solutions, colloids, or emulsions is briefly discussed. The function of emulsifying agents is to form a protective coating

around each droplet of the liquid forming the internal phase and thus prevent coalescence. Soaps are usually used for this purpose, their efficiency being dependent upon the attraction for water of one end of the molecular chain. The efficiency may be increased by the introduction of a basic group which has a greater water attraction than the metals usually used. A number of amines have been found suitable, *e.g.*, triethanolamine, morpholine, and *cyclo*hexylamine. When these amines are used they should be combined with a fatty acid. In the maintenance of a stable emulsion electrical as well as chemical effects exist. When two phases are brought into contact the two surfaces assume equal and opposite charges at area of contact. This is known as the double layer. Methods of breaking emulsions are considered. Where soap is the emulsifying agent the presence of a little water-soluble calcium or magnesium salt will precipitate the soap and destroy the emulsion. When the emulsion is maintained by electrical charge on the droplet a D.C. source of electricity supplied to the emulsion will bring about the change.

Much work is being done on electrophoresis in Britain and in the U.S.A. The author has been successful with the electrodeposition of synthetic resins on to metal in a number of cases. D. K.

Analysis and Testing

2743. Colorimetric method for determining a surface-active agent. G. R. Wallin. *Anal. Chem.*, 1950, **22**, 616–17.—At an acid pH basic fuchsin reacts quantitatively with dodecylbenzene sodium sulphonates and other sulphonates, giving a chloroform-soluble magenta-coloured extract which may be measured in a photo-electric colorimeter. The method is accurate and simple. Side reactions with other groups interfere, although there is no interference from sodium sulphate. Methylene blue behaves similarly to basic fuchsin, but it was necessary to plot a curve because side reactions produced a deviation from Beer's Law. J. S.

2744. Determination of chloride in water. F. E. Clarke. *Anal. Chem.*, 1950, **22**, 553–5.—The paper describes improved colorimetric and titrimetric methods for the determination of chloride ion in water. In both methods, dilute mercuric nitrate solution is added to acified water in the presence of diphenylcarbazone indicator. At the mercury-chloride equivalence point, a blue-violet, mercury-diphenylcarbazone complex forms which is proportional in intensity to the excess of mercury ion present. The colorimetric test is restricted to clear, uncoloured waters without significant heavy metal contamination. The titrimetric procedure is independent of practically all common interference. J. S.

2745. Kelly tube for sedimentation analysis. S. C. Sane, M. K. Shirpurkar, V. V. Deshpande, and M. S. Telang. *Anal. Chem.*, 1950, **22**, 617–18.—Describes a practical device for maintaining the liquid level in the settling tube constant so that the original Kelly equation may be used to calculate the particle-size distribution. This constant-level device is also useful in the precision determination of the angle of inclination of the capillary side arm, as this is used directly in calculating the distribution of the particle size. J. S.

2746. Fractional sublimation on a removable transparent film. A. O. Gettler, C. J. Umberger, and L. Goldbaum. *Anal. Chem.*, 1950, **22**, 600–3.—An apparatus is described for separating the components of a mixture of organic compounds by sublimation at reduced pressures. The sublimate is deposited on a removable plastic film. Microscopic examination of the sublimate, as well as chemical tests thereon, may be performed without removing the sublimate from the film. J. S.

2747. Procedures in high precision ebulliometry. F. N. Hill and A. Brown. *Anal. Chem.*, 1950, **22**, 562–4.—An ebulliometer, designed for stable operations with highly sensitive differential thermometers over a wide range of operating temperatures, is described. This instrument enables the routine use of thermometer-couples of up to twelve times the conventional sensitivity. The application to solutes from 300 to 13,400 average mol. wt. is illustrated with 2% precision throughout this range. J. S.

2748. Electrometric titration of alcohols using lithium aluminium hydride. C. L. Lintner, R. L. Schleif, and T. Higuchi. *Anal. Chem.*, 1950, **22**, 534–8.—Details involved in the development of the electrometric titration of functional groups such as hydroxyl, amino, carbonyl, and carboxyl in organic compounds that react with lithium aluminium hydride are discussed. The method is based on the sharp change in the reduction potential of the system when the last trace of the hydride is removed by the reaction. Silver or platinum wire is used as the indicator electrode and an isolated silver wire as the reference electrode. Tetrahydrofuran is used as the solvent. The method gives relatively good reproducibility. *p*-Aminoazo-benzene is a possible chemical indicator which may be substituted for electrical end-point detection.

J. S.

2749. Derivatives of fatty acids. F. W. Matthews, G. G. Warren, and J. H. Michell. *Anal. Chem.*, 1950, **22**, 514–19.—Three types of derivatives of fatty acids—silver salts, amides, and anilides—have been compared as a means of identification of the acid by use of X-ray-diffraction powder patterns. Each type was found suitable. For ease of preparation and pattern differentiation the silver salt series is preferred. Technical details of powder-diffraction technique for identification are discussed. Tables of diffraction data are given for silver salts of C_2 to C_{22}, amides of C_2 to C_{18}, and anilides of C_{13}, C_{15}, and C_{17}. J. S.

2750. Improved equipment for Engler-type distillations. H. B. H. Cooper and E. C. Medcalf. *Anal. Chem.*, 1950, **22**, 587–90.—Distillation range is an important measure of purity or of general composition for many materials, particularly coal tar and petroleum distillates and various organic chemical intermediates. To minimize fire hazard and improve the laboratory efficiency of the distillation tests, an internal type of electric immersion heater was developed and is described. Excellent agreement has been obtained between distillation-range tests conducted with this heater and those where gas is used as the heating source. J. S.

2751. Determination of sulphur by elementary isotopic analysis. A. D. Kirshenbaum and A. V. Grosse. *Anal. Chem.*, 1950, **22**, 613–14.—The method describes the determination of sulphur using $S^{34}O_2$ as a tracer. The sample is burned with excess of oxygen and equilibrated in a heated quartz vessel with $S^{34}O_2$. In order to concentrate the sulphur dioxide for measurement, the reaction gases are frozen in liquid nitrogen, excess oxygen is pumped off, and the condensed gases (sulphur dioxide, carbon dioxide, and water) are passed back and forth several times over dried calcium chloride to remove the water formed in the burning. The gases are then frozen in liquid nitrogen and allowed to warm up in a dry ice-bath. The liberated carbon dioxide is pumped off and the remaining sulphur dioxide is warmed up to room temp, sampled, and analysed. The percentage of sulphur is calculated from the formula $\% \text{ S} = 100\frac{b(m-n)}{a \times n}$ where a is the weight of the sample, b the weight of heavy sulphur dioxide $S^{34}O_2$, and m and n are the initial and final atomic % excess of S^{34} in the sulphur dioxide. J. S.

2752. Water content of hydrocarbons. W. S. Hanna and A. B. Johnson. *Anal. Chem.*, 1950, **22**, 555–8.—The method described is a modification of the Karl–Fischer method, and is suitable for the determination of water in hydrocarbons or petroleum fractions. The method involves extraction of the water from the hydrocarbons with dry ethylene glycol and subsequent titration of the glycol extract with Fischer reagent. Under normal conditions, over 90% of the water present is absorbed in one extract. Accurate determinations can be made on very dry or relatively wet stocks. J. S.

2753. Evaporation of solvents and thinners. R. J. Curtis, J. R. Scheibli, and T. F. Bradley. *Anal. Chem.*, 1950, **22**, 538–45.—A standard method for measuring the evaporation rates of solvents and thinners has not yet been agreed upon. Investigators have devised a variety of test methods and equipment for this purpose which are largely based upon the evaporation of bulk liquids in disregard of practical use which most frequently involves evaporation of thin films from relatively large surface areas. New

equipment has been devised, and details of this equipment and its use in a variety of applications are described. It is shown that atmospheric humidity, the nature of surfaces from which liquids are permitted to evaporate, and the chemical constitution of the solvents and solutes are significant factors which often assume greater importance in thin-film evaporation than in the evaporation of bulk liquids. J. S.

2754. Polargraphy of chloroform and carbon tetrachloride. I. M. Kolthoff, T. S. Lee, D. Stocesova, and E. P. Parry. *Anal. Chem.*, 1950, **22**, 521–5.—Both carbon tetrachloride and chloroform can be polarographically reduced. Carbon tetrachloride gives two electron-reduction waves, the first corresponding to a reduction to chloroform, and the second to a reduction to methylene chloride. Chloroform gives one wave, which coincides to the second reduction wave of carbon tetrachloride. The height of the wave was found to be proportional to the concentration of the halogenated methane. Procedures are given for the determination of carbon tetrachloride and chloroform separately and in mixtures of the two. A solvent composed of 2 vol of methanol and 1 vol of water with a supporting electrolyte of 0·1*M*-tetramethylammonium bromide was found to be most satisfactory. J. S.

2755. Investigation of the I.F.P. No. 3 Wheatstone bridge hydrocarbon detector. E. Vellinger and R. Monicard. *Rev. Inst. franç. Pétrole*, 1950, **5**, 271–85.—Detector contains two Pt filaments, one of which is in vessel in which gas combustion occurs, thereby raising filament resistance. Apparatus was primarily designed for estimation of hydrocarbons in drilling muds and cores. Detailed study was made of influence of various factors on results obtained, aspects examined included method of gas injection into the apparatus, filament temp, outside temp, diluent gases (H_2S must be eliminated as it inhibits cat activity of Pt, CO_2 in small amounts can be tolerated, although it decreases instrument reading), filament composition, and construction (up to about 10% of Ir increases sensitivity). A detailed description of the operating procedure of the apparatus is given; field trials involving 4000 tests by semi-skilled operators have given satisfactory results. V. B.

2756. Instruments for the determination of rheological parameters of liquid bodies. R. N. Weltman. *J. coll. Sci.*, 1950, **5**, 295–302.—A review of the types of instruments suitable for the investigation of rheological properties of liquids. These are classified into three groups according to the type of information which can be obtained by their use. The merits and disadvantages of the most frequently employed instruments are briefly discussed.

A list of twenty-seven references is appended. H. C. E.

2757. Reduced-scale methods for micro and semimicro organic and inorganic analysis. Part I. T. D. Parks and L. Lykken. *Refiner*, 1950, **29**, (8), 85–8. (*A.C.S. Mtng*, San Francisco, Mar. 1949.)—Details of reduced-scale methods for organic analysis, for the determination of carbon, hydrogen, nitrogen, and sulphur by combustion and of nitrogen by Kjeldahl digestion, and for the determination of organic functional groups including acidity, basicity, saponification number, carbonyl value, ester value, and hydroxyl group. Reduced-scale methods are not only suitable for analysis of small samples (less than 100 mg), but also make possible analysis of peroxy compounds and dinitrophenyl-hydrozones, etc., without serious damaging explosions often experienced with macro-methods, and also reduce the difficulties of corrosion caused by materials rich in phosphorous, halogens, and/or metals. R. W. G.

2758. Gas stability and gas evolution of insulating oils in an electric field. T. Wörner. *Erdöl u. Kohle*, 1950, **3**, 427–36.—New form of apparatus has been developed for measuring gas-evolving and -absorbing properties of oils under stress; two concentric 15-cm glass tubes 1 mm thick and having internal dia 36 mm and external dia 46 mm respectively, 15 ml of oil is required. Applied voltage is 8·5 kV (86% of breakdown val), and stress distribution is fairly even (2·4–2·8 kV/mm). Increasing frequency from 50 to 500 c.p.s. shortens test duration to $\frac{1}{2}$; Raman spectra measurements indicate that oil decomp does not commence until stress application (at 80° C) is for longer than 4 hr at 500 c.p.s. Trials at 20°, 50°, 80° C show general shape of gassing/time curve to be similar, latter temp was selected as being the more severe.

Voltage variation (6·5–9·5 kV) does not markedly affect results. Gas absorption is higher in degassed oils, and hence tests should be carried out on oils saturated with (dry) air so as to make conditions more arduous. Vol of air space above oil surface does not affect general shape of curves obtained. Eight insulating oils (d_{20} 0·875–0·886; visc (cs) at −30° C 727–3660; p.f. (90° C) 0·008—0·037; tar val 0·02–0·10) were examined; test duration 4 hr at 500 c.p.s. All oils showed (in air) initial absorption, followed by evolution; for certain oils the curve then again showed absorption. Initial absorption in air is due to vol reduction caused by O_3 formation (confirmed by tests on empty vessels), subsequent evolution is H_2 and also O_2 from breakdown of oxidn products formed by O_3. In oils again showing absorption towards end of test this is due to addition of H_2 to hydrocarbon mols. Comparative tests on same oil are given for air, N_2, H_2. In N_2 there is evolution, the gas containing H_2, showing breakdown of oil; in H_2 there is absorption. Curves are given showing the four effects that can simultaneously occur (O_3 formation, H_2 evolution, oxidn and decomp of oxidn products, H_2 addition) the net gassing curve being the algebraic sum of these. Gas stability of an oil depends on its chemical composition, and can be improved by additives (not specified). Gas-stability measurements should be carried out in air, not H_2, as former is a more severe and practical test. Oils intended for high-voltage equipment should show no gas evolution. V. B.

2759. Testing of lubricants. C. S. Windebank. *Schweiz. Arch. Ang. Wiss. Tech.*, 1950, **16**, 243–54.—A lecture. Lub-oil tests are classed into: service trials, field tests, rig tests, accelerated rig tests, simulative tests, tests for fundamental properties. These tests give decreasing information, in the order mentioned, but ease (and hence cheapness and practicability) of carrying out increases. In lub-oil testing there is a risk that a test properly assessing the oil may be too long and expensive to do, whilst a simple test will give little or no information. Increasing reliance has to be placed on accumulated experience and supplier status, simple tests being used merely to verify constancy of deliveries. An example is briefly given of how a spec for a new product (gas-turbine lubricant) is built up. V. B.

2760. Engine test bed design. Anon. *Petroleum*, Jan. 1949, **12** (1), 20.—A test bed for high-speed multi-cylinder I.C. engines which is now in use at Esso European Laboratories, Abingdon, is described. It is a spring-mounted structure largely prefabricated by electric welding from mild-steel plate and rolled sections, the framework being filled in with concrete. Transmitted vibration is completely eliminated, and construction and installation of such a bed can be done in a short time with some saving in capital expenditure. An added advantage is that the bed can be easily moved. R. E. P.

2761. Draft [German] standards for liquid fuels. W. Bieler. *Erdöl u. Kohle*, 1950, **3**, 385–9, 446–50.—German standardization committees are working on standard test methods for liquid fuels. It is intended to adhere as far as possible to ASTM/IP procedures. Drafts of the following four methods are given, together with short notes explaining the basis on which they are put forward: DIN 51751, boiling range of fuels for Otto engines (based on IP 123/49); DIN 51754, R.V.P. (based on IP 69/45); DIN 51755, fl. pt. test by Abel-Pensky (closed cup) for materials having fl. pt. 5°–65° C; DIN 51756, knock stability of Otto fuels (methods prescribed are Motor (ASTM D357/47) and Research (ASTM D908/47T)). V. B.

2762. Modern laboratory and plant distillation separation processes using individual assembly components. H. Stage. *Erdöl u. Kohle*, 1950, **3**, 377–83.—Various types of dist separation processes are reviewed. Close relation exists between laboratory and plant results, and use may be made of model laboratory dist for solution of plant problems. Laboratory test apparatus made up of numerous individual components has been developed and is described, with illustrations of the individual parts. Glass or metal may be used, and continuous operation is possible, with vac if required. Main feature of apparatus is claimed to be an inter-column connector whereby extent of fractionation section can be varied. Apparatus is suitable for extractive dist experiments; details are given of a test run for the separation of methyl*cyclo*hexane and *n*-heptane by aid of aniline. V. B.

Crude Oil

2763. Refining properties of new crudes II. Characteristics of crude oils from the Scurry County, Texas, area. N. A. C. Smith, H. M. Smith, and C. M. McKinney. *Petrol. Process.*, 1950, **5** (7), 730–4.—Crude oils from the recently-developed Canyon Reef, Ellenburger and Strawn formations in the Scurry County, Texas, area, are compared on the basis of correlation index with the East Texas and Permian oils of West Texas. The Scurry area crude, from what is probably the most important U.S. discovery since the East Texas field was brought in, is shown to be very similar to that from the latter field, a comparison of the utilization possibilities of the refined products being made. It is quite different from the Permian oils, being much less aromatic in the higher fractions. D. W. F.

Gas

2764. Natural gas.—Its heart and arteries. J. A. Lee. *Chem. Engng*, 1950, **57** (5), 113–17.—Gas reserves in the southwest of the U.S.A. of some 180 trillion cu. ft., are carried to consumers in the north-western, central, and east coast states by pipelines of twenty-one companies. The costs of transmission are assessed in several cases.

Storage capacity, made necessary by winter domestic peak demand, is provided by old, depleted gas wells, or by liquefying ethane and higher hydrocarbons at moderate pressure and temp. High-pressure or low-temp (−250° F) storage is too expensive. D. H.

2765. Ample natural gas supply for Canadian and U.S. Pacific coast markets. Anon. *World Petrol.*, July 1950, **21** (7), 36.—Alberta's gas has been used on a small scale for over sixty years. Now there are several projects for constructing gas-lines from Alberta to the west coast. Government approval is sought. In the course of inquiries it was concluded that Alberta's gas reserves were placed at 7,503,000,000 M.c.f., with 5,947,000,000 M.c.f. marketable. In thirty-six years to the end of 1948 Alberta's consumption of gas was 400,000 M.c.f., but flares probably burned over 1,000,000,000 M.c.f. Nauss considered that reserves of 50,000,000,000 M.c.f. would probably be found. Dodge placed the Pincher Creek reserves at 895,000,000 M.c.f.

Westcoast's gas-line was expected to serve 2,500,000 people by 1955, and would be carrying about 56,000,000 M.c.f/year. A total length of 1570 miles is involved, 426 miles being gathering lines. 24-, 22-, and 14-in pipeline would be used for transmission. The cost would be about $114,000,000 for the pipelines, and $20,000,000 for compressor stations. Laying and coating costs would be $22,000,000. Gas is to be taken from Jumping Pound, Pincher Creek, and Stettler.

Gas-conservation plant has been opened at Leduc. It will ultimately handle 24,000 M.c.f/day.

A line is to be built from Leduc to Edmonton. G. D. H.

Engine Fuels

2766. Developments in the utilization of engine fuels and lubricants. F. L. Garton. *Petrol. Times*, 1950, **54**, 14–18, 52–7; *Schweiz. Arch. Ang. Wiss. Tech.*, 1950, **16**, 279–88.—Gasoline evaluation is reviewed and a comparison made between laboratory and road methods, requirements according to latter usually lie between Research and Motor values. Theory of knocking is briefly considered and action of anti-knock agents, including internal coolants, discussed. Numerous curves are given showing mixture response, octane requirements, etc. Distinction between knocking, pre-ignition, and self-ignition is explained. Problems involved, in connexion with use of T.E.L. in mixture distribution and valve and plug fouling are outlined. Effect of dissolved air on v.p. of fuel is considerable, and is major component at high altitude. Graphs are given showing effect of cetane No. on fuel consumption; diesel knock can be reduced by controlled injection, whereby injection rate is increased after ignition has occurred. Lub-oil requirements of piston engines are considered, together with relative effects of oil, gasoline, and temp on engine deposits. Gas-turbine fuel require-

ments are explained, whilst gas-oil or kerosine-type fuels are safer than gasoline in having a higher fl. pt. they have a lower S.I.T. Aromatic content of turbine fuels has to be restricted to avoid excessive C formation. V. B.

2767. Cold starting performance of high speed diesel engines and their fuels. L. D. Derry and E. B. Evans. *J. Inst. Petrol.*, 1950, **36**, 389–413.—The relation of fuel properties to the starting performance of diesel engines has been investigated; results having been obtained on a single-cyl experimental engine and on six commercially available multi-cyl engines, of both direct- and indirect-injection types. A recording chronograph developed for this work is described.

Cetane number is the most important single fuel property affecting starting performance, with volatility second in importance and, in general, engine performance improves with increase in both these properties. Where volatility is important, diesel index may give a good indication of the relative starting properties of fuels. Some engines are relatively short of excess fuel for starting. In such cases higher fuel viscosity is beneficial and may over-ride the effect of volatility. A. R. W. B.

Lubricants

2768. Alloyed oils. R. D. Streeton and A. C. Mauchan. *Fluid Handling*, July 1950 (8), 239–41; *I.P. Review*, 1950, **4**, 349–57. (*From a paper to Institute of Petroleum, London Branch.*)—The historical development of oil additives is traced. The majority of additives were introduced to improve general properties of lubricants or to reduce refinery operations. Examples of these are pour-point depressants and V.I. improvers. Others were made to overcome special troubles due to mechanical design. E.P. additives of the lead-soap and active-sulphur types were due to the demands of hypoid gears. Oxidation inhibitors like phenyl α-naphthalene were used in turbines and transformers where temperatures are high. Detergent and anti-oxidant oils were not required in I.C. engines until much later, and now account for 60% of all additives. The use of additives enables products to have combinations of properties not possible by refining a mineral stock. Since they comprise only 2% of the cost of the finished oil, the use of additives will be economical for a long time. Synthesized polymers and silicones will become gradually cheaper, but will be limited to special high-duty applications. D. H.

2769. Adhesive properties of lubricating oils. M. Freund. *Petroleum*, Feb. 1949, **12** (2), 29–33.—An apparatus and technique is described to determine the power of adhesion of lubricating oils to solid surfaces. A pretreated and weighed disc of sheet metal is dipped in the oil, allowed to drain, and then fixed on the spindle of a centrifuge and spun to constant weight at a fixed temp and speed. The average thickness of the oil film is the final weight divided by the specific gravity of the oil and the total surface area of the disc.

Results are given for many experiments showing the effect of different surface states, disc materials, and oils. For each temp and speed of rotation there is a limiting value for the thickness of adhering oil, and this depends only on the visc of the oil and the surface properties of the disc. It is independant of the chemical composition of the oil and of the disc material.

It appears that equilibrium is attained with a definite number of monomolecular layers which is independant of the visc and size of the molecule in the oil. Surface forces are apparently ineffective for the thicker oil films. R. E. P.

2770. Anti-friction bearing greases. E. S. Carmichael and R. C. Robinson. *Scientific Lubrication*, May, 1950, **2** (5), 17–18.—The principal characteristics of greases used as lubricants for anti-friction-bearing applications are considered. They include consistency, apparent viscosity, structural stability, resistance against separation of oil, chemical stability, rust-prevention properties, and film-strength characteristics. J. G. H.

2771. Bentone greases. C. M. Finlayson and P. R. McCarthy. *Institute Spokesman*, May 1950, **14** (2), 13–23.—The preparation of bentones from montmorillonite is described, and the physical properties of bentone 34, the one used in the preparation of

bentone greases, are enumerated. The apparatus employed in the laboratory preparation of bentone greases is described. Properties and tests discussed in some detail include working stability and consistency, temperature characteristics, bleeding, corrosive effect, oxidation resistance, adhesion to metals, wear characteristics, water absorption, rust prevention, and low-temperature properties. Details are presented also of wheel-bearing tests, Gulf wheel-bearing tests, and tests in the ABEC machine. J. G. H.

2772. Performance of silicone greases. C. C. Currie. *Institute Spokesman*, June 1950, **14** (3), 10–17.—The physical properties of the four grades of silicone greases available are enumerated, and their application to anti-friction bearings operating at very high temp and low speeds, at temp from −100° to 300° F, as permanent lubricants and for valve lubrication is discussed. J. G. H.

2773. D.C. 200 silicone fluids. Anon. *Scientific Lubrication*, May 1950, **2** (5), 19–22.—The applications of D.C. 200 fluids in lubricating and allied fields are remarked and their classification and general properties enumerated. Visc–temp relations, volatility and vapour pressure, compressibility, surface tension, shear stability, solubility, oxidation resistance, and dielectric properties are also discussed. J. G. H.

2774. Comparative tests with three lubricant testers. R. Halder. *Erdöl u. Kohle*, 1950, **3**, 437–42.—Tests were made with the Almend-Wieland, Falex, and four-ball machines, the loading and film temp under the normal test conditions increasing in that order. Six oils were examined, including rape and three E.P. oils. In the Almend-Wieland tester rape gave the best results, in the Falex best results were obtained with a motor oil incorporating 10% of Cl-containing E.P. additive, whilst in the four-ball tester, in which a much higher temp is encountered, hypoid gear oils gave the best performance. E.P. behaviour of the six oils is discussed on the basis of the detailed results, presented graphically. A good E.P. oil should not have excess surface-activity, else undue wear is caused. Apparent contradictions in the results of the tests on the three machines can be reconciled when conditions (*e.g.*, metal used, surface temp) are considered. Correlation with practice is difficult, and can rarely be obtained by use of one tester alone, limits of test equipment must be borne in mind, and by use of several testers an informative composite picture can be built up, exemplified by curve given for an ideal E.P. lubricant, drawn on co-ordinates of surface activity *v.* surface temp. V. B.

2775. Friction. F. P. Bowden. *Nature*, 1950, **166**, 330–4.—The history of measurement of friction is briefly outlined, and modern work is described more fully.

Methods of measuring the area of contact between solids include : optical microscope, electron microscope, interference methods, and electrical-resistance measurements. It is found that the area of contact is very small, is almost independent of the size of the surfaces, and is directly proportional to the load. Because the contact area is so small movement of one metal over another gives local pressures great enough to cause flow of the metal and welding of the surfaces. This can be shown by radioactive methods, or by detecting fragments of copper adhering to steel after the metals have been in contact and then separated.

It follows that an appreciable normal force is required to separate metals in contact ; and with indium and lead the normal force $\sim$ tangential force for movement. Also, two metals from which all surface films have been removed *in vacuo* exhibit seizure on contact.

Measurements of temp on the surface of sliding solids show that values of 500°–1000° C may be obtained for a duration of $<0{\cdot}01$ sec.

For plastics the coefficient of friction depends upon the structure of the molecule, being about 0·04 for " Teflon," which is a polymer without branched chains. When the surface layers of sintered Cu are impregnated with " Teflon " the resultant material has the mechanical properties of Cu but the coefficient of friction is only 0·05, which is lower than the boundary friction obtained with a good lubricant. H. C. E.

2776. Use of grease for lubrication of railroad passenger roller bearing journal assemblies. W. F. Collins and K. D. Relyea. *Institute Spokesman*, May 1950, **14** (2),

10–12.—Factors leading to the replacement of oil by grease as lubricating medium for railroad passenger-equipment roller-bearing assemblies are discussed, and details presented of a series of service tests on fifteen different greases. The conclusions drawn from these tests indicate that soda-base greases with a penetration of not more than 340, and zero consistency range prove most satisfactory. J. G. H.

2777. Engine design affects lubrication. A. T. Colwell and A. L. Pomeroy. *Scientific Lubrication*, July 1950, **2** (7), 20–2.—The incidence of troubles due to faulty engine design and often attributed to faulty lubrication is remarked, and recent developments in components and practice resulting in improved performance are described. These include valve rotation, flexible steel " 4-Flex " piston-rings, piston finish and correct piston-skirt clearance, cyl sleeves, crankcase ventilation, and oil and coolant temp. J. G. H.

2778. Lubrication—an aid to prevent maintenance. G. D. Jordan. *Scientific Lubrication*, July 1950, **2** (7), 10–13.—The significance of correct lubrication in a planned maintenance system is discussed, and the importance of regular inspection is emphasized. Aspects treated include cleanliness and compatability of lubricant, functioning of the lubricating equipment, wastage and reclamation, consumption control, and plant records. J. G. H.

2779. Multi-functional lubricants. E. M. Kipp. *Lubrication Engineering*, June 1950, **6** (3) 112–16.—The advantage of a system of multi-functional lubricants is discussed, with emphasis on present limitations in user knowledge of lubrication problems generally. The significance of visc data is remarked, and there is suggested a numerical basis for visc values as a limited series of bands, each including a permitted range of viscosities. Stability characteristics and E.P. type lubricants are considered in a similar manner, and a clear understanding of the inter-relationship between operating conditions, physical and chemical properties, and net overall performance is stressed as an essential pre-requisite to material progress in the development of effective multi-functional lubricants. J. G. H.

2780. Lubricating properties of some dry films. A. H. Stuart. *Scientific Lubrication*, May 1950, **2** (5), 10–12, 14.—The theoretical basis of lubrication by dry films is outlined, and the effects of temperature and of oxide films are discussed, together with the lubricating properties of ferrous oxide, sulphides and selenides, molybdenite, graphite, boron nitride, and vermiculite films. The method of applying dry films is explained, and the special properties of graphite films at high temp are noted. J. G. H.

2781. Steam turbine lubrication. Part I. W. E. J. Broom and G. H. Clark. *I.P. Review*, 1950, **4**, 297.—The demands for electricity during the post-war period in Britain have far exceeded generating capacity. The output of modern turbines has also greatly increased, but while an output of 160,000 kW from one turbine is possible, steam-turbines in the U.K. will in the next few years be in units of 30,000 and 60,000 kW capacity with a max steam pressure of 900 lb and temp 925° F. It is, of course, necessary to get the highest efficiency from a plant, and so new turbine oils have been developed. 90% of a turbine oil is employed as a coolant and 10% as a lubricant. The fire hazard is serious, and details of the method employed to reduce it are given. Mention is made of new types of oil reservoirs which are in more easily accessible places than previously. The situation and operation of the main and auxiliary oil-pumps are described. Water surface coolers are universally fitted to modern turbines; their positioning is important. Solid drawn steel piping is exclusively used in modern units to reduce risks of bursting. The use is described of hydrogen-cooled alternators, which are claimed in the U.S. to be advantageous. R. H.

2782. The graphoid surface and the oil film. E. A. Smith. *Petroleum*, Apr. 1949, **12** (4), 85–5.—The graphoid surface is an extremely thin film of graphite, which is formed on the rubbing faces of mechanical equipment lubricated with oil-containing colloidal graphite. It shows low friction characteristics and is very strongly adsorbed to the metal face on which it lies. Electron diffraction shows that the surface is made up of hexagonal sheets which lie more or less parallel to the substrate. In this position the

graphite offers max lubrication, providing such lubrication by slipping along the well-defined cleavage planes.

X-ray diffraction and other experiments show that the surface has strongly adsorptive properties and the oil molecules are " anchored " to the metal surface. Thus such a surface reinforces lubrication by its properties and also assists the oil film in its work, improving oil spreading and adhesion.

The surface offsets seizure and reduces wear of metallic faces, and therefore offers an all-round improvement in lubrication. R. E. P.

Special Hydrocarbon Products

2783. Vinyl aromatic compounds. VII. 1 : 3 : 5-Trivinylbenzene. D. T. Mowry and E. L. Ringwald. *J. Amer. chem. Soc.*, 1950, **72**, 2037–8.—1 : 3 : 5-Trivinylbenzene was prepared by the catalytic vapour-phase dehydration of 1 : 3 : 5-tris-(α-hydroxyethyl)-benzene at 400° C and 125 mm pressure over activated alumina. The material was found to be slightly more effective than pure *p*-divinylbenzene as a cross-linking agent in the polymerization of styrene. W. H. A.

2784. Highly refined mineral oils. G. Cibula. *Erdöl u. Kohle*, 1950, **3**, 397–9.—Highly refined oils are known as " white oils," subdivided into " technical white oils " (having a marked yellow tinge) and " pharmaceutical white oils," which are almost colourless, completely colourless oils are known as " paraffina liquida." Term " vaseline oil," hitherto used for half-white oils, is misleading and should be discarded. " Light " or " thin " white oils have visc 3–5° E_{20}, " heavy " or " thick " oils 7–12° E_{20} or more. Main uses of white oils are outlined. For liquid paraffin DAB VI specifies sp. gr. >0·870, and visc >15° E_{20}. V. B.

2785. Use of petroleum oils in plant protection. M. F. Williaume. *Bull. Ass. franç. Tech. Pétrole*, 1950 (83), 55–67.—History of plant-protection oils is briefly reviewed, and present-day views on desirable properties therein are considered. White oils have toxic action against only a limited group of insects, but their scope as insecticide carriers is considerably wider, moreover, in combination with insecticides appreciable synergic effects occur. As weed killers naphthenic and asphaltic oils are more suitable than paraffinic. Mode of action of mineral oils as toxic agents towards insects, fungi, and plants is discussed. V. B.

Derived Chemical Products

2786. Chemicals : their production and consumption by the petroleum industry. E. Ayres. *Petrol. Process.*, 1950, **5** (7), 726–8.—The chemicals discussed are those produced by the petroleum industry as distinct from the organic chemical industry. These are mainly fuels and lubricants, including alcohol, acetone, butadiene, and toluene. The effects of wide use of the Fischer-Tropsch process using natural gas on the alcohol industry are considered. The future use of coal will yield great quantities of chemicals now produced from petroleum. D. W. F.

2787. Petroleum as a raw material for the chemical industry. J. C. G. Boot. *Schweiz. Arch. Ang. Wiss. Tech.*, 1950, **16**, 272–9.—(See Abs. No. 874, 1949.)

Coal, Shale, and Peat

2788. Extraction and refining of shale oil. B. Guthrie and L. Schramm. *Mech. Engng.*, Sept. 1950, **72** (9), 707.—In view of a tremendous increase in demands for oil and diminishing of nation's capacity to produce oil, an oil shortage became a possibility in the U.S.A. during the last war. Authority was given to Bureau of Mines to establish demonstration plants, pilot plants, and research laboratories for supplementing petroleum products with liquid fuels produced especially from oil shale and coal. The paper describes the nature and characteristics of oil shale, explains how oil is obtained from the rock, describes the crude shale oil obtained and the methods and equipment being used at Rifle, Colo., to refine this oil. It is explained that in the

U.S.A. there are larger and richer deposits of oil shale than in most other countries and that the reason a shale-oil industry has not so far been developed in the U.S.A. is because there has been sufficient petroleum to meet the demands of the country. Furthermore, the price of petroleum has been considerably lower than the selling price of shale oil could possibly have been. Now, however, the price of crude is increasing sharply, and this, together with advances in the technology of mining and processing oil shale and of refining shale oil, is bringing the costs of liquid fuels from petroleum and oil shale close to the same level. A. S.

2789. Development of a mobile compressor and utility station. F. D. Wright and H. J. Ballinger. *U.S. Bur. Mines Rep. Invest. No.* 4709, July 1950.—Development, construction, and operation of a compressor and utility station are described. It is one of the largest mobile units ever constructed, and is used at the Rifle, Colorado, experimental shale-oil mine. The unit has two 770 cu. ft/min air compressors, a 200 cu. ft. air receiver, and a 2500 gal water tank. The unit measures 30 by 12 ft and weighs 30 tons. Its performance is described, and it is shown that power consumption is 0·421 kW/hr/ton of shale broken as compared with 0·531 kW/hr/ton consumed by the stationary plant formerly used for the purpose. Brief details are given of the Rifle mine and also of the drilling carriage used. W. H. C.

Miscellaneous Products

2790. Manufacture and application of copper naphthenate. A. Davidsohn. *Industr. Chem.*, 1950, **26**, 385–9.—Naphthenic acids for Cu naphthenate manufacture are generally obtained from suitable pet distillates by extraction with caustic alkali, removal of unsaponifiable material from the soap, and acidifying with dilute sulphuric acid. The purified naphthenic acids should be of 170–230 acid val and contain not more than 15% unsaponifiables. Two main methods of manufacturing Cu naphthenate are: (*a*) precipitation from sodium naphthenate solution with copper sulphate, (*b*) fusion of naphthenic acids with copper acetate. Latter method is cheaper since it is finished in one operation, but product is darker coloured, and more skill is necessary during manufacture. Other methods have been patented; details and patent references are given. Uses of Cu naphthenate are as fungicide (in solution in pet solvents, Cu content $\not<6\%$ in U.S.A., $\not<9{\cdot}5\%$ in British spec) in wood preservation, frequently mixed with aluminium or zinc naphthenate; for protection of textile fabrics, tents, ropes, sandbags, nets, etc.; as a fungicidal component of paints; and as a suggested component of insecticidal oil sprays. A. C.

2791. Carbon black manufacture. Anon. *Paint Mnfr.*, Oct. 1950, **20** (10), 357.—The installation at Ellesmere Port is described, and photographs are included. The use of liquid hydrocarbon as the raw material enabled fully reinforcing black to be produced economically in Britain.

Refinery residues are fed as required to two tanks and maintained at elevated temp. The hot liquid is fed into refractory-lined furnaces with sufficient air to give controlled partial combustion. A number of furnaces constitute a unit, and the flues from each meet in a manifold leading to the cooler and collector system. The furnaces are filled with a mass of luminous flame, producing temp above 2500° F. The flue gases carry the suspended black up the stack, where water sprays reduce the temp to about 400° F. The cooled dry gases are then passed through a 75-kV dry Cottrell electrostatic precipitator. Some black is precipitated, but the bulk is flocculated into aggregates which remain in the gas stream. The stream is passed through a set of three cyclone collectors, and the black is removed by centrifugal action. It is collected and conveyed to the pelletizers. As the black is fed in water is added and pellets are formed; these are then dried and packed. Treatment of waste gases is discussed. A flow sheet of this process for the production of "Vulcan 3" carbon black is included. Advantages of this method include: utilization of exhaust gases obviating the purchase of fuel, the ability to use a cheap petroleum refinery residue rather than more valuable distillates, the flexibility of the process (it can produce several grades of black). Necessary ancillaries to the plant and the future of the industry are discussed. The contractors and suppliers of the plant are listed. D. K.

CORROSION

2792. The nature and scope of temporary corrosion preventives. D. Clayton and M. C. Thompson. *J. Inst. Petrol.*, 1950, **36**, 423–8.—A description is given of the usual types of temporary corrosion preventives together with some of the newer developments. The field of use is defined and the principal causes of failure reviewed; the contribution of important accessory properties is mentioned. Finally, some of the questions arising in accelerated testing are raised. A. R. W. B.

2793. Assessment of the protective value of temporary corrosion preventives (with particular reference to humidity cabinet tests). T. G. Clinton. *J. Inst. Petrol.*, 1950, **36**, 428–35.—The factors likely to produce breakdown of temporary corrosion preventives under service conditions are considered, and certain performance tests applicable to the assessment of the protective qualities of such coatings are discussed. The use of a humidity cabinet and an intermittent salt-spray test are described in detail. Accelerated weathering, continuous salt spray, and natural weathering tests are mentioned. The view is expressed that there is no individual performance test available at present which is likely to forecast the behaviour of protectives under all types of service. A. R. W. B.

2794. Use of weatherometer and humidity cabinets for evaluation of temporary corrosion preventives. W. Pohl. *J. Inst. Petrol.*, 1950, **36**, 436–48.—A humidity cabinet, commercially available in the U.K., has been compared with a weatherometer, which is described, for the testing of temporary corrosion preventives. It was concluded that the weatherometer was to be preferred; it was unsuitable for quantitative work in that no absolute figure for "life" could be given (which varied from test to test) but it was suitable for qualitative studies and provided a reasonable basis for comparison.

The use of other types of humidity cabinet is under investigation. A. R. W. B.

2795. A method for the evaluation of soft film temporary corrosion preventives for ferrous articles. T. P. Hoar and G. C. Smith. *J. Inst. Petrol.*, 1950, **36**, 448–57.—A new technique for the assessment of soft-film temporary corrosion preventives is described. A very thin but reproducible film is deposited from a volatile solvent on to a clean steel surface, and the incidence of corrosion due to small drops of distilled water is determined after 24 hr.

The technique has been used to evaluate the relative protective value of several compositions of mineral jelly (specification C.S. 1317) with amphipathic substances. The composition of three parts mineral jelly with one of lanolin is shown to be a considerably better protective than the plain jelly, and to be further improved by the substitution of wool-grease for lanolin. The addition of 2% (solids) of sodium petroleum sulphonate to any of the above compositions greatly improves their protective value.

The results are discussed in terms of the adsorption of a firmly held monolayer of amphipathic substance on the oxide-film surface of the metal. A. R. W. B.

2796. Application of an accelerated atmospheric corrosion test to the assessment of temporary corrosion preventives. R. St. J. Preston and E. G. Stroud. *J. Inst. Petrol.*, 1950, **36**, 457–63.—An accelerated atmospheric corrosion test, in which specimens are exposed in a thermostatically-controlled humid atmosphere containing sulphur dioxide, has been applied in the assessment of temporary corrosion preventives. The protectives included materials ranging from light lubricating oils, through petroleum jelly, to bitumen.

The average order of failure of steel panels coated with the protectives, exposed in various parts of the U.K. in unheated sheds, approximated to that obtained in the laboratory test of one week's duration.

A plain humid atmosphere was insufficiently aggressive to break down most of the samples, in spite of a prolonged period of test. A. R. W. B.

2797. Tests of the protective value of temporary corrosion preventives on steel. S. G. Clarke and E. E. Longhurst. *J. Inst. Petrol.*, 1950, **36**, 463–73.—Results are presented

on corrosion tests carried out by relatively simple methods. Free exposure to the outdoor atmosphere, the A.R.E. salt-spray test, and a non-streaming humidity test gave comparable orders of merit for several protectives on steel. Outdoor exposure is generally too severe and variable for testing oil films. Increasing protection with rising film weight of lanolin was demonstrated in an outdoor test. A sprayed-on water-droplet test discriminated between oil films. A marked reduction in the weight of steel corroded in the A.R.E. salt-spray test was produced by extremely thin oil films. A. R. W. B.

2798. Temporary corrosion preventives for aviation uses and methods of testing them. E. W. J. Mardles and J. Mason. *J. Inst. Petrol.*, 1950, **36**, 476–87.—Mention is made of the numerous temporary corrosion preventives, including corrosion-preventive lubricants, which have been used in connexion with aviation. Special features of temporary corrosion preventives are briefly discussed. Methods of test are treated in the order: Exposure, Accelerated, Mechanical, Special Tests for Engine Corrosion Inhibitors, Other Laboratory Tests, and Norma–Hoffmann Bomb Oxidation Tests. A number of results by the last-named method are discussed, and attention is drawn to the interest and importance of this method in testing and developing temporary protectives and other products. A. R. W. B.

2799. American methods of testing temporary corrosion preventives. C. F. McCue and E. R. Blane. *J. Inst. Petrol.*, 1950, **36**, 487–94.—A critical review is presented of the more important methods used in America, both in the laboratory and in the field for assessing the degree of protection afforded by temporary corrosion preventives. The significance of results obtained with some of the tests is discussed, and work is quoted which demonstrates that, whereas no single test can be relied upon always to correlate well with practice, a better assessment can sometimes be obtained by considering the results of two or three different tests in conjunction. A. R. W. B.

2800. Performance tests, other than corrosion tests on temporary corrosion preventives. H. Hollis. *J. Inst. Petrol.*, 1950, **36**, 495–504.—Brief details of the methods of test currently used in the performance testing of temporary corrosion preventives are discussed. Tests used for the evaluation of protective properties are not dealt with as they are fully covered in other papers in the symposium. A. R. W. B.

2801. Sulphur in your crude oil? It's not how much but where. W. C. Uhl. *Petrol. Process.*, 1950, **5** (7), 729.—Corrosion troubles from sulphur are believed to be due to the S content of some of the lighter fractions and the processing operating temp, and not to the original crude S content. A corrosion case history at Gulf Oil Corp's 230,000-b.d. Port Arthur refinery reveals that severe corrosion occurred in the atmospheric tower, overhead condenser shells, and radiant section of the fuel heater, even though the crude charged was relatively sweet. D. W. F.

2802. Cathodic protection goes offshore. E. P. Doremus and G. L. Doremus. *Oil Gas J.*, 22.6.50, **49** (7), 222.—Corrosion on offshore structures is most severe in the splash-and-spray zone. In this area, however, coatings can be applied and renewed as necessary. Underwater corrosion is most severe just above the mud line and just below the tidal zone, these sections being anodic. Coatings have only a short life when submerged, and cannot be renewed. Experience with cathodic protection indicates that corrosion can be practically eliminated on submerged portions and reduced considerably in the tidal zone. Polarizing of the surface to be protected is effected by applying high-current densities of 50–350 mA/sq. ft. for a few days. This causes deposition of a calcareous coating, and subsequent current requirements are reduced to 3 mA/sq. ft.

A platform with a submerged area of 25,000 sq. ft. will require at least 1250 amp for polarization and 75 amp for protection. This current is generally obtained from sacrificial magnesium anodes. For the polarization current magnesium ribbon with an iron core giving approx 0·5 amp/ft is used. The ribbon is completely consumed in seven to ten days. For subsequent protection 51 lb magnesium anodes are used suspended from the platform by copper or steel cable. Connexion to the platform

may be made through a shunt and a current-limiting resistor. A 51-lb anode is generally rated at 1·8 amp for two-year life.

Pipelines connected to the platform if coated and wrapped will receive protection for several miles. It is important that barges be kept isolated from the platform so that a heavy load on the protective system is avoided. Such protection can be applied to any cases of corrosion by salt water, and many applications are possible in the petroleum industry.

The possibility of using rectified A.C. with graphite anodes should be borne in mind if cheap electric power becomes available. C. G. W.

2803. Surveying pipe lines for reconditioning data. J. R. Cowles. *Oil Gas J.*, 21.9.50, **49** (20), 270.—Oklahoma Natural Gas Co. uses surface-potential surveys to afford a reliable method of determining serious corrosion on bare and poorly-coated pipelines.

Measurements are made of potential differences in millivolts between conventional copper sulphate electrodes placed on the surface of the ground.

Skill is required to interpret results, but to field men observing the work the data are definite.

Crew of three men, or preferably four, is used for the work, and cost of equipment is moderate. G. A. C.

2804. Cures for corrosion in gas condensate wells. W. H. Stewart. *Petrol. Engr. Ref. Ann.*, 1950, **22** (7), B-35.—The organization and scope of research projects on corrosion in gas-condensate wells are described. Field and laboratory experience with inhibitors are briefly described, organic inhibitors being most satisfactory. Coatings require further testing before their efficiency is established. Alloy tubing at present undergoing test has so far proved extremely resistant to attack. C. G. W.

Engines and Automotive Equipment

2805. Progress review No. 11 : Piston type oil engines. Anon. *J. Inst. Fuel*, Sept. 1950, **23** (133), 263.—For increased power without increased weight or bulk some manufacturers mainly in road transport and marine propulsion fields, have favoured the two-stroke cycle, while others, particularly in the industrial and rail-traction fields, have turned to pressure charging the four-stroke-cycle engine. There has been a noticeable extension of the oil-engine range towards smaller cylinder size and higher r.p.m. The general trends in design of piston-type oil-engines are discussed. A recent development for the pressure-charging of two-stroke engines is the utilization of exhaust pressure waves to force back into the cylinder some of the scavenge air that has passed to exhaust during an earlier part of the gas-exchange period. A recent American development consists of supplying air to the engine at a fairly high pressure, through a cooler, and obtaining further cooling in the engine cylinder by closing the inlet valve appreciably before bottom dead-centre in order to expand the air before re-compressing it on the succeeding stroke, by this means a high output can be obtained without risk of breakdown. The most noticeable development in increasing reliability, the period between overhauls, and the normal life of components has been the extended use of chromium plating. With increasing rotational speeds and increasing loads, torsional vibrations have become a serious problem. Recent advances in the technique of bonding rubber to metal have resulted in new types of rubber coupling. Other subjects discussed include : the extension of the range of fuels that can be used satisfactorily, the improvement of combustion and thermal efficiency, the ease of starting, extension of the principle of standardization and changeability of components, extension of the field of usefulness of any basic model of engine, improvement of accessibility and simplification of maintenance, mechanical simplification, reduction of manufacturing time and costs, improvement of mechanical efficiency, minimization of risk of crankcase explosions and experimental developments. Seventy-nine literature references. D. K.

2806. Progress in marine propulsion (1910–1950). K. C. Barnaby. *Trans. Inst. mar. Engrs*, Sept. 1950, **62** (9), J1.—The above is a joint paper read before The Institution of Naval Architects and The Institute of Marine Engineers. It covers

forty years' development in marine propulsion, and describes briefly the changes involved during this period. At the start of the period under review there were no vessels with geared turbines and there were no ocean-going motor ships. However, development work on large oil-engines began to flourish, and before the end of 1910 Sulzer and Werkspoor diesel engines were in use in two ships with great success. At about the same time, the first two passenger-ships to be powered by geared turbines were in use. One of these is still in regular service. The progress made during the first world war is summarized by describing a number of the vessels produced during that time. The arrival of the Michell thrust is described in connexion with geared turbines with which an improved thrust block becomes a necessity. Progress in reduction gearing design is summarized and examples quoted of the serious initial difficulties. Various papers are then listed on the question of steam *v* diesel, and in this connexion a large number of performance figures are given. Gas turbines for marine application are mentioned briefly, and finally the progress in hull and propeller design is summarized. A. S.

2807. Prospects of gas turbines in naval applications. R. T. Simpson and W. T. Sawyer. *Mech. Engng*, Sept. 1950, **72** (9), 712.—It cannot be said, as it can of the aeronautical gas turbine, that a marine, locomotive, or naval gas turbine is a vital necessity. The existing machinery for those three applications is far from being unsuitable, outmoded, or insufficient for the task assigned. In those fields the gas turbine must show a positively advantageous balance against its competition to justify the development of even a moderate size of gas-turbine installation. From an analysis of a large number of vessels operating over an extended period of wartime running it is revealed that upper 80% of installed h.p. is used for less than 4% of operating life of vessel; 70% for less than 1%; and 60% for less than 0·3%. Representative figure for machinery weights associated with steam-propulsion plant of vessels studied is 16 lb/h.p. This means that in a 60,000-h.p. twin-screw vessel for 99% of operating life of vessel 300 tons of propulsion machinery are carried against sudden requirement for more than 30% power. Practicability of replacing this top 70% of installed power, which is required to operate for only 1% of life of vessel, with a relatively short-life gas-turbine weighing between $\frac{1}{2}$ and 2 lb/s.h.p. is attractive and appears feasible. One of the several potential arrangements for accomplishing this is described. A. S.

2808. The gas turbine and its combustion problems (1). I. Lubbock and I. G. Bowen. *Petroleum*, Jan. 1949, **12** (1), 8–11.—The paper, presented at the Birmingham Joint Conference of the Institutes of Fuel and Petroleum, gives a condensed account of the technical considerations underlying both the many fields of application and the many forms which a gas turbine may take.

A brief treatment of gas turbine thermodynamics is followed by an account of problems associated with the combustion of liquid fuels. Two outstanding problems are discussed: first, the gas turbine must operate at lower cost than its competitors, second, the equipment must have considerably longer life than its aircraft equivalent.

A typical combustion chamber for heavy fuel oil burning is described. Problems of air delivery, its effect on the flame and atomization of the fuel are outlined. A description of a multiple-tip burner suitable for a wide range of fuel requirements is also given. Special mention is made of the problems associated with the burning of heavy fuel oils and the economics and practical aspects of heat exchangers.

R. E. P.

2809. The gas turbine and its combustion problems (2). I. Lubbock and I. G. Bowen. *Petroleum*, Feb. 1949, **12** (2), 37–9.—Originally presented at the Birmingham 1948 Conference on Liquid Fuels, the second part of the paper deals with specific applications of the gas turbine.

Each section shows how the choice of fuel affects the particular case, and points out distinctive features in the combustion and heat-exchanger systems. Locomotive power plants, marine power plants, power production, and some industrial processes, *e.g.*, the Houdry catalytic cracking process, are briefly outlined. All sections emphasize the need for continued development of the combustion system and turbine to make use of heavy fuel oil. R. E. P.

2810. Gas turbine progress at Pametrada. Anon. *Gas Oil Pwr*, 1950, **45**, 193–7.—Marine gas turbines differ from aircraft turbines in that their anticipated life must be much greater, and they must be able to use residual fuels. Their advantages over marine steam-turbines are their greater efficiency and greater flexibility in installation and service.

The experimental turbine at Pametrada develops 3500 h.p. at a propellor speed of 85 r.p.m. and at present burns diesel fuel, although it is intended to use boiler fuel later. One difficulty in the use of heavy fuels is the presence of vanadium, which gives rise to compounds which clog the turbine blades and corrode the steel.

A diagrammatic arrangement of the gas-turbine cycle is given. After a two-stage axial-flow compression to 66 p.s.i. the air passes through a heat exchanger. Fuel and air are then mixed in the combustion chambers and the gas admitted to the high-pressure turbine at 1200° F, driving the compressors. After reheating to 1200° F the gas passes through the output turbine. Details of the compressors, combustion chambers, turbines, and heat exchangers are given.

The fuel is injected through swirl-type sprayers axially disposed in the combustion chamber. It is normal to start on refined fuel and transfer to heavy fuel after warming up. Ignition is effected by means of a hot wire.

It is hoped in the future to produce a water-cooled gas turbine which will run at 2200° F with the object of improving the efficiency. H. C. E.

2811. The helicopter pressure jet. F. L. V. Doblhoff. *Aero Engng Rev.*, Sept. 1950, **9** (9), 36.—A review is presented of the inherent characteristics of pressure jet drive systems for helicopters, and their advantages over the conventional system of shaft-driven rotors are put forward.

Jet engines become increasingly adaptable to helicopter propulsion as their performance is improved, because low specific consumption is fortunately achieved with the same turbine outlet conditions that lead to small duct area, *i.e.*, high pressure and low temp. Exhaust cooling, regeneration, or turbine ducting must be employed in order to reach the extremely low specific consumption necessary to bring about satisfactory blade conditions. Thermodynamic cycles can be devised that will permit a combination of limited component efficiencies, low temperatures, low fuel consumption, and suitable rotor-drive air conditions. Satisfactory blade duct conditions can be achieved, even with inefficient basic jet engines, by modification of the cycle, but power-plant development for specific helicopter purposes would be required.

By resorting to tip-burning, use can be made of existing power plants. Specific consumption is higher than that of a turbo-jet engine, but the system can be used advantageously for power boost over the normal hovering power or when rotor propulsion is used only for short periods of the total flying time. Includes four literature references. U. N.

2812. M.A.N. tractor diesel engine. Anon. *Gas Oil Pwr*, 1950, **45**, 197–9.—This four-cylinder engine has cylinders of stroke and bore 110 and 88 mm respectively and runs at 1500 r.p.m. to give an output of 25 h.p.

The combustion chamber in the piston crown is spherical, and the fuel is injected through a single nozzle of orifice dia 0·7 mm. The max fuel consumption is 0·385 lb/b.h.p.hr. The piston-rings are of molybdenum–cast-iron alloy, and the top ring is chromium-plated to withstand corrosion.

Forced-feed lubrication is employed from a gear-type pump, but the piston-rings are splash lubricated. All outlets such as shafts, etc, are sealed against dust, and the fuel-pump is completely enclosed for dust protection. H. C. E.

2813. A.E.C. railcars for G.N.R. (Ireland). Anon. *Gas Oil Pwr*, 1950, **45**, 207–9.—The power units of these railcars are A.E.C. 9·6-litre, six-cyl direct-injection engines with open toroidal combustion chambers and masked inlet valves. The cyl have bore and stroke of 120 and 142 mm, and the units develop 125 b.h.p. at a max speed of 1800 r.p.m. The compression ratio is 16 : 1.

The power drive is via a fluid flywheel, five-speed pre-selective epicyclic main gearbox and 2-speed auxiliary gearbox. The gears are changed by means of compressed air, and all the engine controls are air-operated.

The max speed attainable is 70 m.p.h. with a tractive effort of 1360 lb. The max tractive effort is 12,400 lb. H. C. E.

2814. National B4A and B4AU diesels. Anon. *Gas Oil Pwr*, 1950, **45**, 204–6.—These engines have bore and stroke of 17 and 21½ in respectively, and at their max speed of 333 r.p.m. they develop 167 h.p./cyl on the 12-hr rating, equivalent to a b.m.e.p. of 81 p.s.i.

Fuel consumption is 0·345 lb/b.h.p.hr at 300 r.p.m. Graphs of fuel consumption and exhaust temp against b.m.e.p. are given.

The engines are built in a normally-aspirated or exhaust-pressure-charged form, and can be supplied as dual-fuel or spark-ignition types. They are available in sizes from five to eight cyl, and cover a power range from 835 to 2000 b.h.p. at max speed.

H. C. E.

2815. A simple and effective engine starter. Anon. *Mech. World*, 15.9.50, **128** (3322), 253.—The handraulic starter, which is an engine starter capable of being applied to all types of engines, but is particularly useful for oil-engines, is hand operated. There are only three moving parts, two toothed racks and a pinion, and working within a closed circuit it does not rely on any outside source of energy. The most important part of this unit is a hydraulic accumulator containing a synthetic-rubber diaphragm. The reservoir is filled initially with compressed air at 2000 p.s.i., and is then sealed. It never requires recharging, as there is no leakage. Hydraulic fluid pumped into the lower part of the accumulator by means of a hand-pump compresses the air at the back of the diaphragm to approx 4000 p.s.i. In the charged state the pressures on both sides of the diaphragm are equal, and it is therefore not subjected to any strain. When air only is in the accumulator, the diaphragm rests against the inside walls of the reservoir. The starter unit comprises two opposed cylinders each containing a piston-rack which engages with a simple pinion. This pinion is integral with a toothed dog which engages with a corresponding dog on the engine crankshaft. On releasing control lever, energy stored in high-pressure air in accumulator is transmitted through the medium of hydraulic fluid to starter. Control lever operates two-stage valve, the first stage admitting sufficient pressure to starter to engage it with crankshaft. During second stage when dogs are fully engaged, oil at full pressure is admitted to heads of piston-racks and crankshaft is rotated at high speed and with high starting torque.

Dogs are automatically disengaged when engine starts. A. S.

Safety Precautions

2816. New practices for eliminating accidents in offshore operations. J. T. George. *Petrol. Engr Ref. Ann.*, 1950, **22** (7), B-90.—The necessity of working a 12-hr day on offshore operations makes fatigue and mental strain an important factor in rig accidents. The only practicable measures to be taken are: (1) good food, (2) clean, comfortable quarters, (3) availability of diverse reading matter, (4) careful selection of personnel. Personnel for offshore operations must be physically fit and able to swim. A large portion of accidents on offshore operations may be attributed to boats, and close co-operation with marine personnel is essential.

High guard rails, elaborate fire precautions, etc, must be standard equipment.

C. G. W.

2817. Earthing of oilfield equipment. O. Sander. *Erdöl u. Kohle*, 1950, **3** (6), 271–4.—Fatal accidents are commonly caused by the accidental or intentional touching of the housing of electrical equipment which is at a high tension due to damaged or dirty insulators. Examples of how this can occur are given. Protection is necessary not only against high-tension power supplies but also against static electricity and lightning. Recommended types of earths and earthing practices are described.

S. E. C.

Miscellaneous

2818. Man's use of energy. H. Hartley. *Nature*, 1950, **166**, 368–76. (*Presidential Address delivered to the British Association*, Aug. 1950.)—This lecture is an historical review of sources of energy and their development through the ages. Of particular interest is an estimate of the gross annual intake of energy of all kinds in terms of coal,

and the proportion of this met by solid fuel, liquid and gaseous fuels, and water-power. Developments and future possibilities in the utilization of energy, and the efficiency of present methods, are discussed. H. C. E.

2819. Energy for process industries. Anon. *Chem. Engng*, 1950, **57** (5), 104–12.—Statistics on American production reserves, location, and price cover coals, petroleum, natural gas, and water-power from 1939 to 1949. The second part is an abstract of the 1947 Census of Manufacturers showing the proportions of each fuel used by thirty-eight process industries. D. H.

2820. Technical developments in 1948 in the American petroleum industry. F. Heinemann. *Petroleum*, Apr. 1949, **12** (4), 86–9.—A review is given of developments in the American oil industry during 1948. Sections are devoted to oil prospecting; drilling and drilling apparatus; recovery and treating of oil and natural gas; refining; desulphurization; conversion; regeneration of catalysts, etc.; cracking; hydrocarbon synthesis; polymerized hydrocarbons; liquid fuels; heavy oils; greases; waxes, and petrochemicals. 125 references are given, all referring to publications made in 1948. R. E. P.

2821. "Six tenths factor" applies to complete plant costs. C. H. Chilton. *Chem. Engng*, 1950, **57** (4), 112–14.—Following an article (*Chem. Engng*, June 1949, **56** (6), 97–106) showing that the cost of individual plant items is proportional to the 0·6 power of the capacity, data are presented to show that this rule can be extended to complete plants. This is a rough approximation which does not hold where the capacity of the plant is achieved by multiplying units, or in pilot plant, where the size of certain units is limited by practical considerations.

Exponents for the thirty-six types of plant given lie mainly between 0·33 and 0·82. D. H.

2822. Mid-Valley operates 1000 mile microwave relay system. D. Samuelson. *Oil Gas J.*, 21.9.50, **49** (20), 302.—The sub-carrier multiplex microwave relay network system for the Mid-Valley Pipeline Co.'s, St Louis, 1000-mile crude-oil line from Longview Sea to Lima, Ohio, is described.

Overhead telephone wires are disrupted by storms, and two-way radio over long distances unreliable, but with the ultra-high-frequency system virtually uninterruptible communications along the pipeline can be maintained.

The system includes thirty-six repeater stations, spaced 14–37 miles apart, and complete static-free and noise-free reception is achieved. G. A. C.

2823. Natural gasoline and cycle plants in the United States, January 1950. *U.S. Bur. Mines Inf. Circ. No.* 7576, July 1950.—Tabulated data are given of natural-gasoline and gas-cycling plants in operation in the U.S. on Jan. 1, 1950, and comparisons are made with operations two years previously. The location, daily capacity, type of plant, viz. absorption, compression and charcoal, fractionation, cycling, and other processes are recorded. The total output on Jan. 1, 1950, was 27,212,000 gal, of which 67% was produced in absorption and 24% in cycling plants, the total number of plants being 554. During the period covered, absorption-plant capacity increased and cycling plants decreased. The use of compression, charcoal, and other types of processing continued to decrease. W. H. C.

2824. Bibliography on petroleum products. S. E. Winn. *Institute Spokesman*, June 1950, **14** (3), 24–28, 32.—A bibliography by Gulf Research and Development Co. covers books and pamphlets, in English only, under the following divisions: petroleum (general), petroleum chemistry and refining, petroleum tests, asphalts, cutting oils, fuel oils, gasoline, greases, lubricants and lubrication, naphthas, and waxes. J. G. H.

2825. Apparatus for the laboratory study of gas absorption in packed towers. H. J. Strauss. *Chem. Education*, Sept. 1950, **27** (9), 517.—Very few satisfactory laboratory studies of gas absorption in packed towers have been developed for educational purposes. At the Cooper Union there has been developed an experimental

gas-absorption system which has overcome most of the objectionable features of conventional laboratory units and has many desirable points. The latter include the complete elimination of any analytical work, and the practically complete elimination of any gas-film resistance. In addition to studying the characteristics of a gas-absorption apparatus, the data obtained can also be used to calculate mass transfer coefficients, H.T.U.s, and gas-solubility equilibria. A description is given of the apparatus from the points of view of construction and operation. A. S.

2826. Oil developments in Italy. A. Giordano. *Petroleum*, Jan. 1949, **12** (1), 12–13.—Problems of fuel economy have re-awakened interest in Italian indigenous oil and natural-gas resources. Geologists believe that important oil resources may be located in many areas, but no definite information has been published. While waiting for exploration results work has been concentrated on the exploitation and extension of the gas resources already discovered. Many pipeline networks are under construction.

Several extension programmes have been approved by the government for oil refineries. Capacity of existing refineries is to be increased besides construction of three new refineries in the north. The quality of oil products is also to be improved.

R. E. P.

2827. The application of radioactive tracer techniques to the study of the movement of oil in sands (2). S. E. Coomber and E. N. Tiratsoo. *Petroleum*, Aug. 1950, **13** (8), 191–3.—The second part of the paper, the first part of which appeared in the July issue, deals with the measurement of oil distribution in sands in dynamic conditions. Illing's experiments on migration and accumulation at interfaces were repeated to study conditions and experimental technique. Details of these experiments with results are given. It is shown that quantitative measurement of oil in sand can be made and its course traced. Possible future research to improve and extend the method is also discussed. This includes improvement of instrumental technique, detailed investigation of adsorption of the isotopes on to minerals, and application of the technique to the evaluation of the properties of rocks containing various fluids.

R. E. P.

2828. Project engineering. D. Gordon. *Chem. Engng*, 1950, **57** (3), 125–36.—Describes the principles of project engineering—the design, procurement, erection, and trial operation of new chemical plant. It stresses the complexity of organizing the project, and on this account recommends that in most cases it should be left to a firm specializing in the subject. D. H.

2829. Non-destructive inspection. D. H. Stormont. *Oil Gas J.*, 7.9.50, **49** (18), 69.—A new dye-penetrant method of inspection locates quickly small surface cracks, and flaws, and examines castings, forgings, and machined surfaces. Fatigue cracks in engines and all types of machinery can be found.

A red dye is applied to cleaned surface of suspected part, excess removed, and a "developer" applied. Presence of a surface discontinuity is indicated by the red penetrant bleeding into the white coating formed by "developer."

The compounds employed are non-corrosive, can be applied by brushing, spraying, or dipping. G. A. C.

2830. Electric arc welding of cast iron. A. M. Hill, F. W. Zilm, and C. E. Spencer. *Oil Gas J.*, 21.9.50, **49** (20), 232.—The technique of making repairs to heavy machinery, simplification of maintenance, and reduction of costs are dealt with. Preparation of casting for welding, selection of welding electrodes and equipment are points for economical operation. Method of welding cyl-heads of diesel engines is outlined.

G. A. C.

2831. Progress review No. 12 : Atmospheric pollution. A. Marsh. *J. Inst. Fuel*, Sept. 1950, **23** (133), 267.—The consequences of atmospheric pollution are discussed. It has been observed that heavy fog in urban areas has frequently been accompanied by a significant rise in respiratory deaths. The investigation of atmospheric pollution is directed by the D.S.I.R. through its Atmospheric Pollution Research Committee and the Fuel Research Station. The progress or absence of progress in reducing pollution

during the post-war period is reviewed by brief notes on each of the principal sources. These sources are : domestic pollution, general industrial pollution (smoke and grit), and pollution from specific industrial processes (railways, power-stations, cement works, burning colliery spoilbanks, etc). A concise comprehensive statement and explanation of the general legislative position is given in Sheer's " Law of Smoke Nuisances." The principal legislation for England and Wales is contained in the Public Health Act, 1936. There are also a number of new local Acts. Overseas progress, particularly in the U.S.A., is discussed. There are eighty-five literature references. D. K.

BOOK REVIEWS

The Science of Petroleum. Volume V, Part I. Crude Oils : Chemical and Physical Properties. General Editors : Benjamin T. Brooks and A. E. Dunstan, 1950. The Oxford University Press. Pp. 200. 48*s*.

The field of petroleum technology advances its frontiers so rapidly that any book on the subject needs frequent revision and supplementation if it is to remain up to date. It was therefore inevitable that additional volumes would be required to supplement the first four volumes of the " The Science of Petroleum." These were published in 1938, and because of the intervention of the war and the difficulties of printing and publishing which have followed it, these supplementary volumes are long overdue. Petroleum technologists will therefore note with satisfaction that these volumes have now begun to appear, and they will be more than content to know that, both in matter and presentation, the high standard of the first four volumes has been well maintained.

Volume V will be issued in three parts, and will deal with the chemistry, physics, and chemical engineering of petroleum. As yet only Part I is available, and the subject matter of this is presented in two Sections dealing with : (1) Crude Oils, and (2) Chemical and Physical Properties of Petroleum Hydrocarbons. The individual articles have been contributed to a very large extent by Americans, owing, as the general editors observe, to the fact that in the war years greater progress in petroleum technology was made in the United States than in Europe, where research was of necessity restricted.

Section 1 occupies about a quarter of the volume. Here is gathered together a wealth of analytical and other data about crude oils and the products of crude oils from oil-producing areas in the western hemisphere and the Middle East. Special mention must be made of the full treatment accorded to the crude oils of the U.S.A. in an article which also includes data for annual production and estimated reserves. The methods of characterizing and evaluating crude oils in relation to the properties of the products which may be derived from them are dealt with in another article, and the section appropriately ends with an account of the developments which have enabled the industry to keep pace with the rapidly growing world-wide demand for oil.

Section 2 in the first place provides data concerning the nature and the quantity of the hydrocarbons present in various natural, straight-run, and cracked gasolines, and presents existing knowledge of the composition of kerosines, gas oils, lubricating oils, and petroleum waxes. Subsequent articles describe the reactions of the paraffin, naphthene, aromatic, olefin, and diolefin hydrocarbons, and a clear exposition is given of the mechanism of organic reactions in the light of simple electronic theory of chemical bonding. There is an excellent report of the work of the National Bureau of Standards on the isolation and identification of hydrocarbons in petroleum ; the processes used for their separation are described, and a summary is given of the information so far obtained from the study of the gas, gasoline, kerosine, and lubricant fractions of petroleum. A further article summarizes the data on the thermodynamic properties of various classes of hydrocarbons obtained as a result of the work carried out on A.P.I. Research Project 44, and the final contribution reviews the data related to vapour–liquid equilibria at the high pressures involved in the production of natural gas and crude oil.

Here then, as the first instalment of a volume which no technical library can afford to be without, is a rich well of information. The publishers, the editors, and

the authors deserve the congratulations and thanks of all those who will seek, and will find, the same quality of service in the present Part that they found in the earlier volumes.

It is fitting to mention here that the general editors, Benjamin T. Brooks and A. E. Dunstan, had the assistance of eight advisory editors, namely M. R. Fenske, F. H. Garner, E. R. Gilliland, J. Bennett Hill, D. A. Howes, E. V. Murphree, Frederick D. Rossini, and K. M. Watson. The titles and the authors of the individual articles are as follows :—

Section 1.

The Crude Oils of the U.S.A., 1935–45	H. M. Smith
The Crude Oils of Venezuela	Gulf Refining Company
The Crude Oils of Saudi Arabia	Arabian-American Oil Company
The Crude Oils of Bahrein Island	J. R. Keith
The Crude Oils of the Middle East	D. A. Howes and L. C. Strang
Evaluation of Crude Oils and Oil Stocks	W. L. Nelson
Economic Developments in the Petroleum Industry	O. Tokayer

Section 2.

Hydrocarbons in Petroleum	A. N. Sachanen
The Chemistry of Paraffin Hydrocarbons	J. Habeshaw
The Chemistry of Naphthene Hydrocarbons	W. J. Oldham
The Chemistry of Aromatic Hydrocarbons	W. J. Oldham
The Chemistry of Olefine and Diolefine Hydrocarbons	F. A. Fidler
Mechanism of Organic Reactions	F. C. Whitmore and N. C. Cook
The Fractionation, Analysis, and Isolation of Hydrocarbons in Petroleum	B. J. Mair and F. D. Rossini
Chemical Thermodynamic Properties of Hydrocarbons	F. D. Rossini
High-Pressure Vapour-Liquid Equilibria in Cycling Operations	D. L. Katz and M. J. Rzasa

C. M. C.

Petroleum and its Products* (Twenty-Fourth Annual Priestley Lectures.) 1950 : W. J. Sweeney. The Pennsylvania State College, U.S.A. Pp. 146. $2·45.

The Priestley Lectures were inaugurated at the Pennsylvania State College in 1927, and in a foreword to the present volume it is stated that the original concept for these lectures " was three-fold in nature : (1) to establish a living memorial for Joseph Priestley ; (2) to honor a succession of contemporary American scientists ; and (3) to demonstrate that theoretical chemistry was a vital functional part of modern applied chemistry." The high standard set by previous lecturers has been well maintained in the series under review, and the author, who is Vice-President, Research and Development, of the Standard Oil Development Company, is to be congratulated upon the amount of up-to-date information he has incorporated.

The subject matter of the lectures is presented in five chapters under the titles : I. Occurrence, Production, and Resources of Petroleum ; II. Composition and Analysis of Petroleum ; III. Refining of Petroleum ; IV. Chemical Products from Petroleum ; V. Utilization of Petroleum Products. The text is supplemented by a total of seventy-two figures and twenty-four tables, in the preparation of which the author has enlisted the help of numerous experts in the different fields covered.

In Chapter I a short account is given of the origin and accumulation of petroleum and the methods of finding oil by geological survey, geophysical prospecting, and random drilling. Cable-tool and rotary methods of drilling are compared. The oil-producing areas of the world are enumerated, and future oil supplies and requirements are discussed.

Reference is made in Chapter II to recent progress in the detailed evaluation of crude oil and the development of new techniques which have made possible the separation and identification of the individual hydrocarbon types. Stress is laid upon the importance of a knowledge of the proportions of hydrocarbon types in different petroleum fractions as basic data for research and development of refining processes. The recent work of the National Bureau of Standards and the Pennsyl-

* Copies obtainable from Phi Lambda Upsilon, Dept. of Chemistry, Pennsylvania State College, State College, Pennsylvania, U.S.A.

vania State College is reviewed, and much information of value is presented in the twenty-one figures and sixteen tables included in this chapter.

In Chapter III the refining of petroleum is considered under the two main headings of Separation and Conversion Processes. Under the former heading atmospheric and vacuum distillation, gas absorption and recovery, and solvent-extraction methods are discussed, whilst under the latter heading reference is made to the newer processes involving catalytic cracking, hydroforming, catalytic polymerization, alkylation, and isomerization. Numerous flow plans and photographs of plant are used to illustrate the text.

The phenomenal growth of the petrochemical industry during the past twenty-five years provides the main theme of Chapter IV. It is shown that whereas in 1925 less than 0·1 per cent of the total U.S. organic chemical production was derived from petroleum sources, the corresponding figure in 1945 was 50 per cent. Two major developments are largely responsible for this change, the one being the more efficient separation of the lower-boiling constituents of petroleum by modern fractional distillation, and the other the availability of such compounds as ethylene, propylene, and the butylenes as by-products from the newer refining processes. It is also regarded by the author as probably significant that the growth of the petrochemical industry has closely coincided with the increased commercial production of synthetic rubbers, fibres, and plastics. The processes by which the various organic chemicals are obtained from hydrocarbon raw materials are described and set out diagrammatically, and the production of new types of polymers is reviewed. Reference is also made to the development of the "Hydrocarbon Synthesis" (Fischer–Tropsch) process for the production from natural gas of gasoline and diesel fuel as well as alcohols and other oxygenated chemicals.

Chapter V outlines progress and development in the utilization of petroleum products, and indicates many important milestones in the past 100 years. Changes in the production figures of the major products are set out in graphs and tables, and the factors influencing these changes are discussed. Considerable space is devoted to fuels, the properties and fundamental requirements of motor, aviation, diesel, turbine, and burner fuels being reviewed at some length. Dealing with the subject of lubricants, emphasis is laid on the steadily increasing demands on the lubricant resulting from the higher speeds, higher loads, and reduced clearances characteristic of modern engines and machinery, and on the correspondingly greater need to maintain in the lubricant "an optimum balance of desirable properties" to suit the many types of equipment and conditions of use which are now encountered.

This volume of Priestley Lectures embodies an authoritative review of modern petroleum technology, and although some of the information it contains is primarily intended for the student, much remains to interest and enlighten the expert.

J. P.

Abbreviated Title	*Journal*
J. appl. Mech.	Journal of Applied Mechanics.
J. appl. Phys.	Journal of Applied Physics.
J. Coll. Sci.	Journal of Colloid Science.
J. Econ. Ent.	Journal of Economic Entomology.
J. Electrochem. Soc.	Journal of the Electrochemical Society.
J. Inst. Cert. Engrs, S. Africa	Journal of the Instn Certified Engineers, South Africa.
J. Inst. Fuel	Journal of the Institute of Fuel.
J. Inst. mar. Engrs.	Journal of the Institute of Marine Engineers.
J. Inst. Petrol.	Journal of the Institute of Petroleum.
J. Iron & Steel Inst.	Journal of the Iron and Steel Institute.
J. Oil Col. Chem. Assoc.	Journal of the Oil and Colour Chemist's Association.
J. Palæont.	Journal of Palæontology.
J. Phys. & Colloid Chem.	J urnal of Physical and Colloid Chemistry.
J. sci. Instrum.	Journal of Scientific Instruments.
King's Highway	King's Highway.
Laboratory	The Laboratory.
Lubr. Engng	Lubrication Engineering.
Mech. Engng	Mechanical Engineering.
Mech. World	Mechanical World.
Mikrobiologiya	Mikrobiologiya.
Mod. Plastics	Modern Plastics
Motor Ship	Motor Ship.
Nafta	Nafta.
Nature	Nature.
New Engl. J. Med.	New England Journal of Medicine.
New Zealand J. Sci. Tech.	New Zealand Journal of Science and Technology.
Oil Forum	Oil Forum.
Oil Gas J.	Oil and Gas Journal.
Paint Manfr	Paint Manufacturer.
Paint Technol.	Paint Technology.
Petroleum	Petroleum.
Petrol. Engr	Petroleum Engineer.
Petrol. Process.	Petroleum Processing.
Petrol. Tech.	Journal of Petroleum Technology.
Petrol. Times	Petroleum Times.
Pipe Line News	Pipe Line News.
Proc. Roy. Soc.	Proceedings of the Royal Society.
Producer's Monthly	Producer's Monthly.
Public Roads	Public Roads.
Rds and Streets	Roads and Streets.
Refiner	Petroleum Refiner.
Rev. Inst. franç. Pétrole	Revue de l'Institut Française du Pétrole et Annales des Combustibles Liquides.
Rev. Pétrolière	La Revue Pétrolière.
Rev. sci. Instrum.	Review of Scientific Instruments.
S.A.E. Trans.	Transactions of the Society of Automotive Engineers.
Schweiz Arch. Ang. Wiss. Tech.	Schweizer Archiv für Angewandte Wissenschaft und Technik.
Scientific Lubrication	Scientific Lubrication.
Soap Sanitary Chem.	Soap and Sanitary Chemicals.
Summary Op. Calif. Oilfields	Summary of Operations of California Oilfields.
Times Rev. Ind.	Times Review of Industry.
Trans. Faraday Soc.	Transactions of the Faraday Society.
Trans. Inst. chem. Engrs	Transactions of the Institute of Chemical Engineers.
Trans. Inst. mar. Engrs	Transactions of the Institute of Marine Engineers.
Trans. Roy. Soc. Canada	Transactions of the Royal Society of Canada.
U.S. Bur. Mines Inf. Circ.	U.S. Bureau of Mines Information Circular.
U.S. Bur. Mines Rep. Invest.	United States Bureau of Mines, Report of Investigations.
World Oil	World Oil.
World Petrol.	World Petroleum.

APPLICATIONS FOR MEMBERSHIP OR TRANSFER

DECEMBER 1950

The following have applied for admission or transfer to the Institute. In accordance with the By-laws, the proposals will not be considered until the lapse of at least one month after the publication of this *Journal*, during which time any Fellow, Member, or Associate Member may communicate by letter to the Secretary, for the confidential information of the Council, any particulars he may possess respecting the qualifications or suitability of the candidate.

The object of this information is to assist the Council in grading the candidate according to the class of membership.

The names of candidates' proposers and seconders are given in parentheses.

Applications for Membership

BAYLEY, Leonard Charles John, lubricants supervisor, Shell-Mex & B.P. Ltd. (*H. E. Priston ; A. Moon.*)

COBBETT, Robert Frank, departmental sales manager, Gulf Oil (Great Britain) Ltd. (*L. O. Maskell ; A. Graham.*)

CURTIS, Garth Douglas, assistant power engineer, National Oil Refineries Ltd. (*H. Murphy ; E. J. Horley.*)

FAWCETT, Peter, laboratory oil tester, Manchester Oil Refineries Ltd. (*G. H. Harries ; N. A. Clegg.*)

GEYRA, Igal, assistant to installation manager, Shell Co. of Palestine Ltd. (*S. Jaszunski ; E. Dawidson.*)

GREAVES, Walter Clifford, technical superintendent, National Oil Refineries Ltd. (*J. A. Green ; E. J. Horley.*)

HILL, Richard William, technical representative, Messrs. Pegson Ltd. (*L. A. Mountford ; G. W. W. Ford.*)

KING, Albert Leslie, executive officer (Administration), Shell-Mex & B.P. Ltd. (*A. J. Foster ; G. L. Coles.*)

LAHIRI, B. N., Ordnance Consulting Officer, Army Headquarters, India.

MILLER, Laurence Hubert, assistant process operator, National Oil Refineries Ltd. (*E. J. Horley ; P. F. Ellis.*)

PILLING, Robert Wood, shift superintendent, Petrochemicals Ltd. (*E. M. Cordova ; L. Jeffreys.*)

ROBINSON, William, field engineer, Ecuador Oilfields Ltd. (*A. J. Fincham ; G. Sell.*)

TANNER, Gerald Humphrey, senior designer draughtsman, Messrs. Foster-Wheeler Ltd. (*A. Tate ; G. Sell.*)

UDEN, Robert, lubricants representative, Shell Petroleum Co. Ltd. (*H. E. Priston ; A. Moon.*)

Transfers

CHARLES, Eric John, chemical engineer, Petrocarbon Ltd. (*F. H. Garner ; R. Morton.*) (*Student to Associate Fellow.*)

FAULKNER, Brian Alex, research chemist, Esso Development Co. Ltd. (*E. B. Evans ; A. Osborn.*) (*Student to Associate Fellow.*)

GRIFFITHS, Thomas Haydn, assistant mechanical engineer, National Oil Refineries Ltd. (*E. J. Horley ; P. F. Ellis.*) (*Student to Associate Fellow.*)

GROVE, Ronald Garfield, assistant operator, National Oil Refineries Ltd. (*E. J. Horley ; P. F. Ellis.*) (*Student to Associate Fellow.*)

ROE, John Guy Ainsworth, petroleum technologist, Government of Trinidad. (*W. N. Foster ; I. S. Rutherford.*) (*Associate Member to Fellow.*)

SNOW, Percy Henry, chief chemist, Eclipsol Oil Company Ltd. (*E. R. Redgrove ; J. C. James.*) (*Member to Fellow.*)

WAKELING, Roy Gerald, trainee driller, Bremer Well Drilling Co. Ltd. (*W. Donald ; P. Hicks.*) (*Student to Associate Fellow.*)

NEW MEMBERS

The following elections have been made by the Council in accordance with the By-laws.

Elections are subject to confirmation in accordance with the By-laws.

As Fellow

BLOTT, J. F. T.

As Members

BOOKEY, J. T. B.
CUNLIFFE, H.

As Associate Fellows

HUGHES, F.
McINTOSH, H. J.
NOLAN, J.
PENZIAS, W.
WEBBER, W. G.
WOODFINE, R. J.
WRIGHT, L. D.

As Associate Members

CUSHING, A. H. S.
KIELL, F. J.

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SMITH, J. L.

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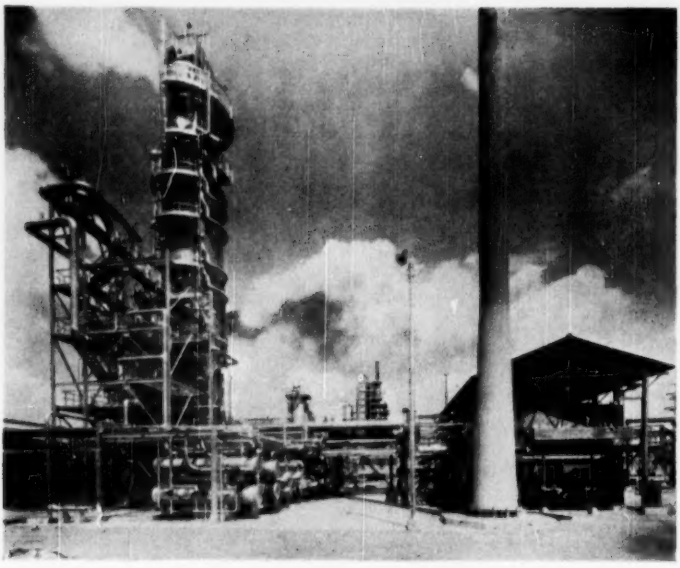

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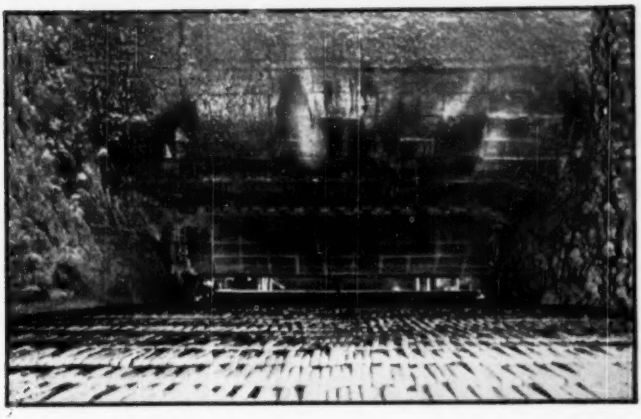

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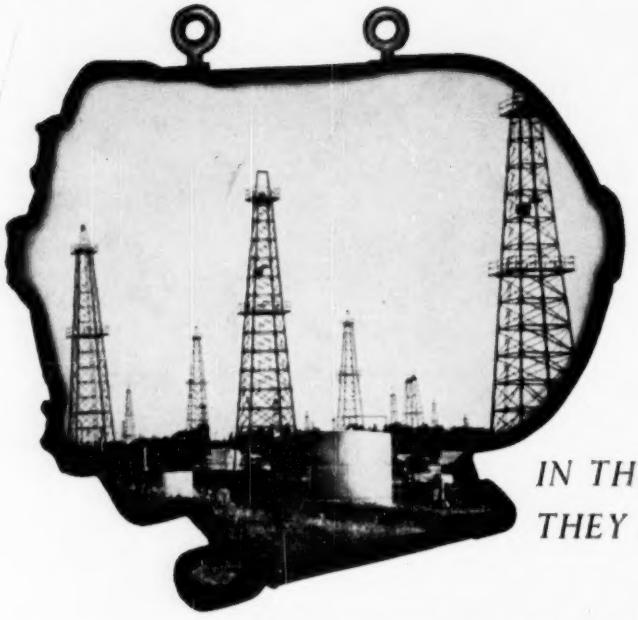

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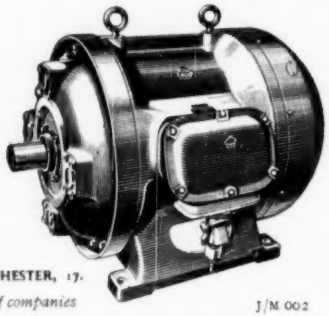

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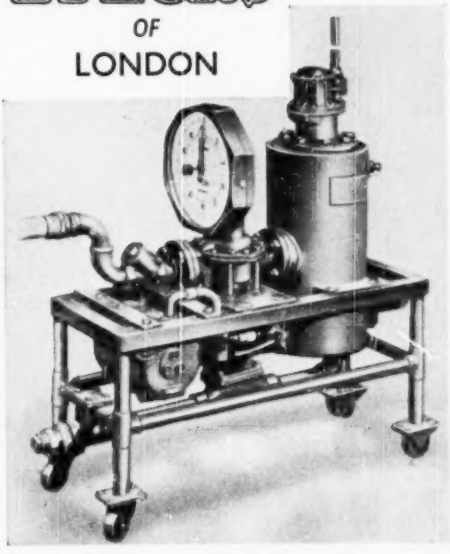

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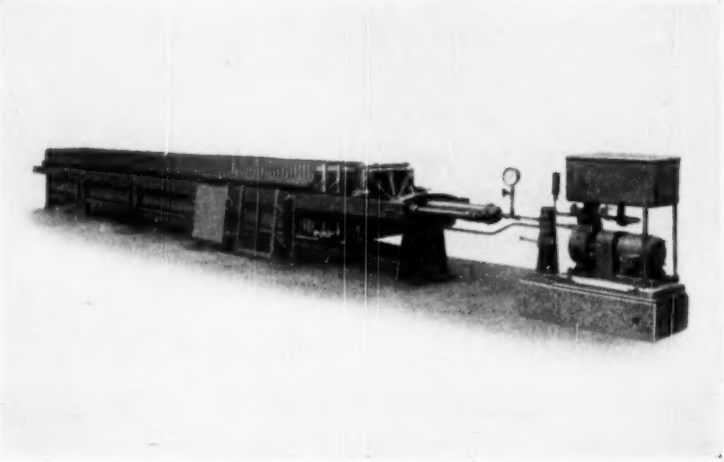

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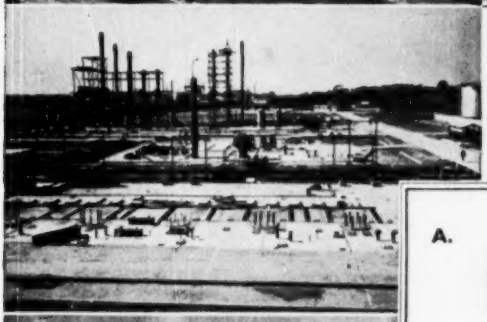

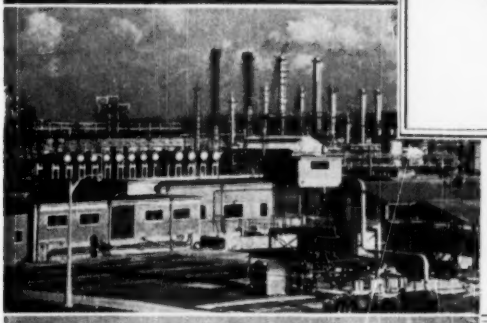

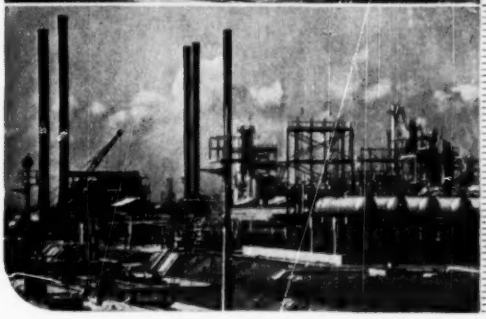

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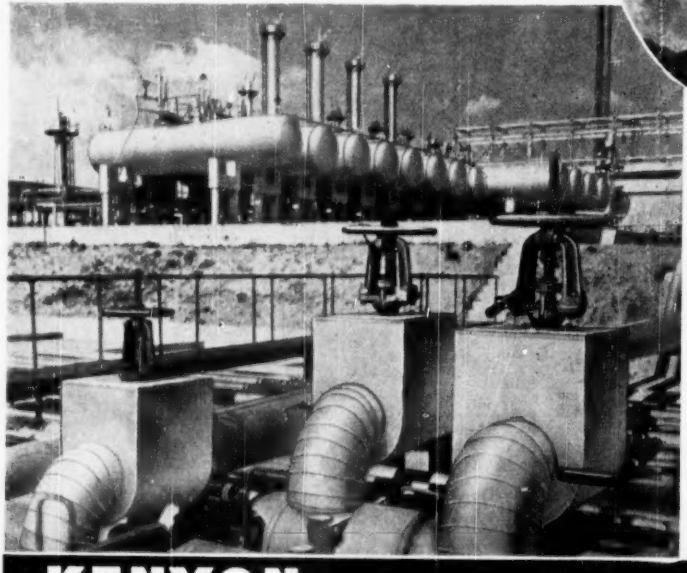

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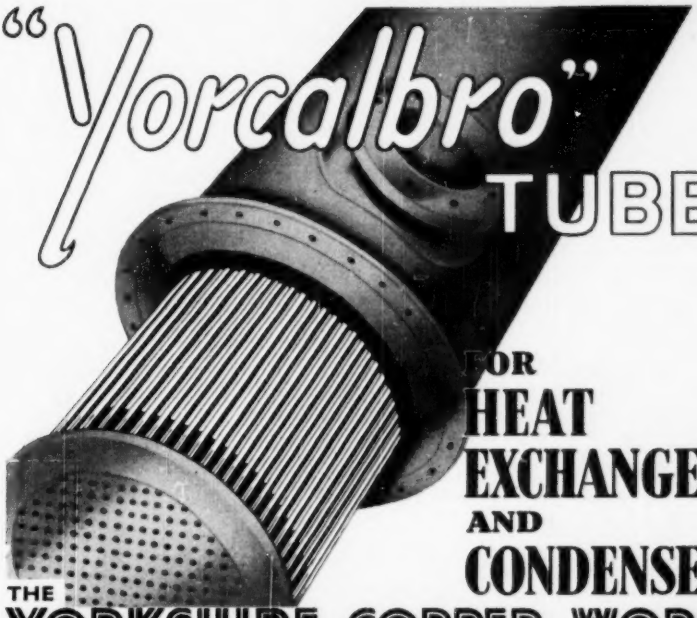

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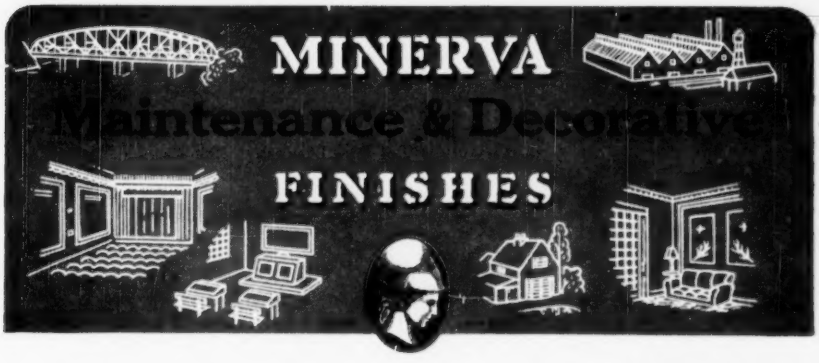

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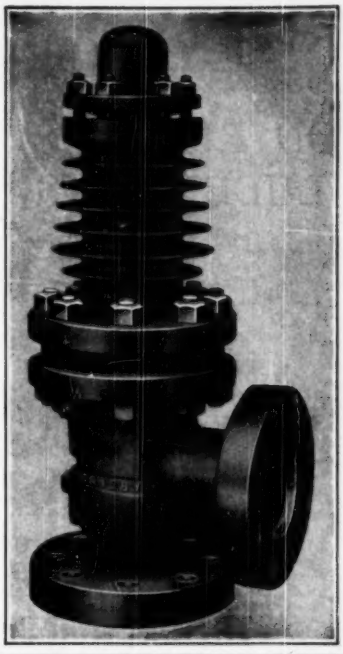

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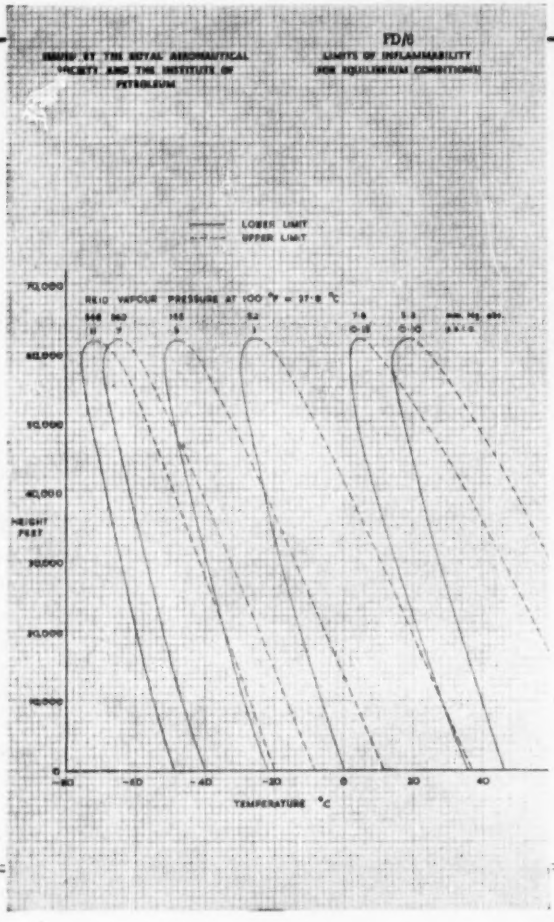

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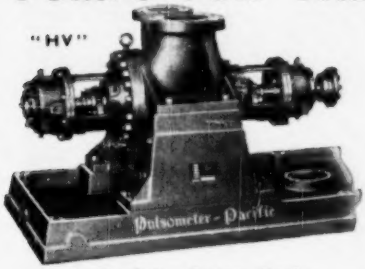

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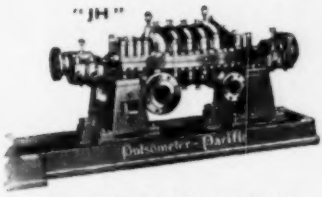

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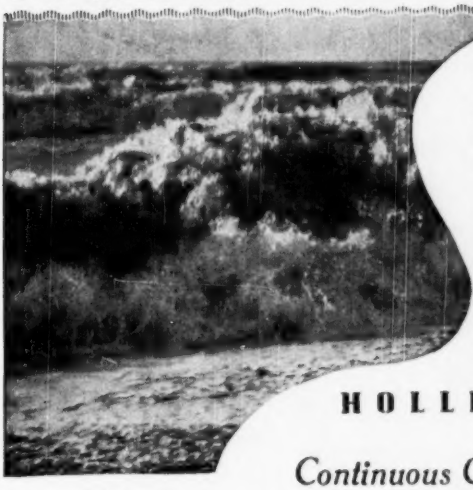

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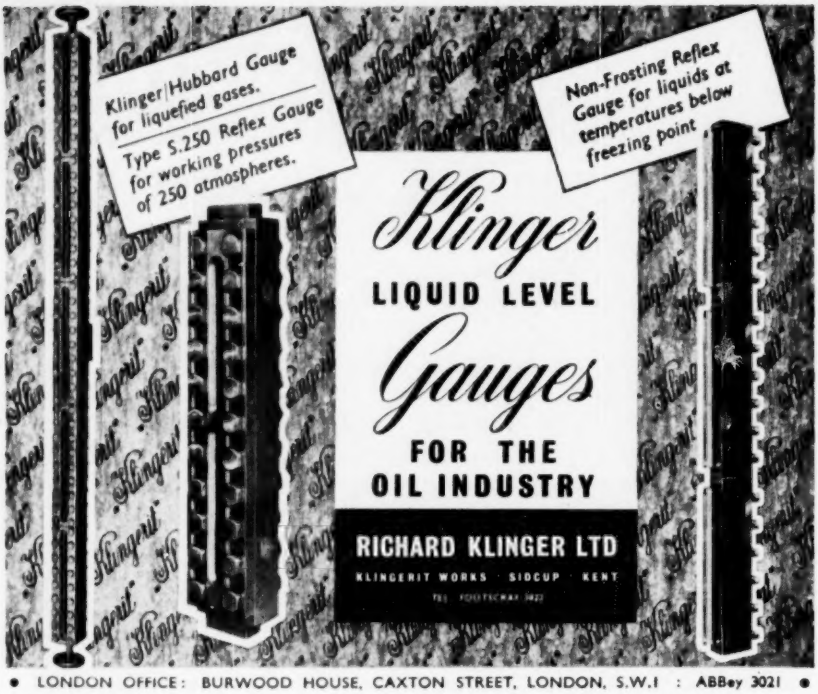
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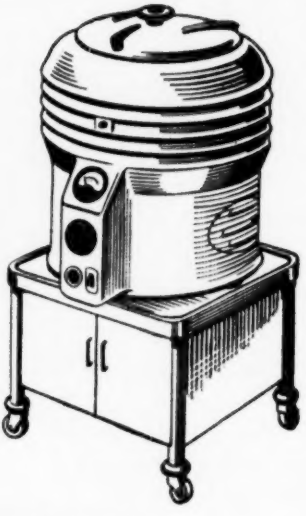

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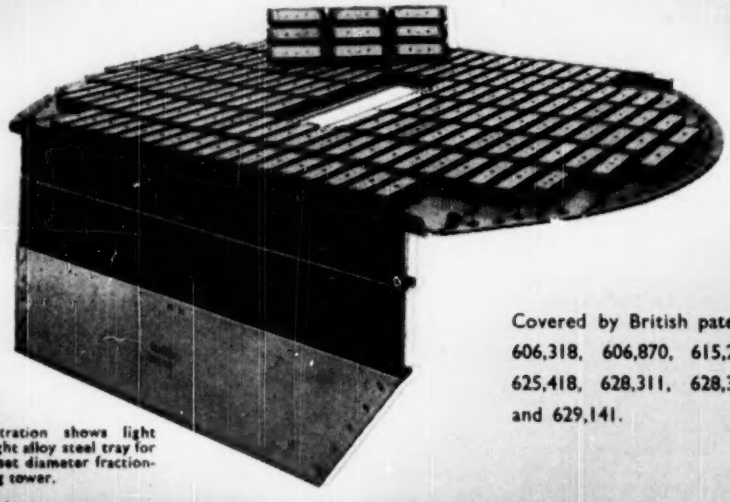

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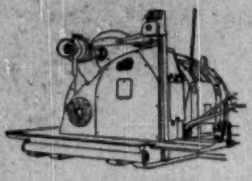

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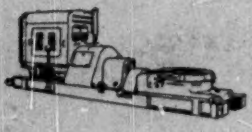
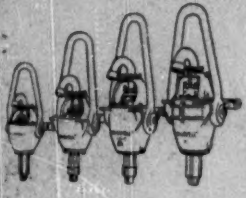
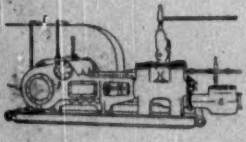


"OILWELL" ROTARY DRILLING UNITS are noted for their smooth operation and flexibility. They are available with two forward and one reverse gears. All "OILWELL" ROTARIES have the same general construction, and differ only in size and capacity.



"OILWELL" SWIVELS, recognized for their advanced design, have been used on many of the world's deepest wells. Four sizes, ranging from 100 to 400 tons capacity, provide a choice for any drilling requirement.



"OILWELL" PUMPS include a wide range of models suitable for every oil-field application. From the huge No. 220-P Power Slush Pump to the small No. 6P-HD for general service use, they embody construction features based upon time-proved design.

Whether you need a complete drilling rig or only a single item remember "OILWELL" is a good place to buy all your oil-field equipment and supplies.

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